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COMMUNITY REACTION TO AIRPORT NOISE

Vol. I

Prepared by
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for

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16. Abstract

This report describes a study of the relationships of large numbers of variables--physical, psychological, and social--with community reaction to the noise of aircraft around international airports in large U.S.A. cities. The seven major airports involved were Logan International-Boston, O'Hare International-Chicago, Dallas International-Dallas, Stapleton International-Denver, Los Angeles International-Los Angeles, Miami International-Miami, and Kennedy International-New York.

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FOREWORD

This survey was performed by TRACOR, Incorporated under NASA Contract NASW-1549. The work was done under the auspices of the Office of Advanced Research and Technology, NASA Headquarters, specifically under the Environmental Systems and Effects Division.

This report describes a study of the relationships of large numbers of variables--physical, psychological, and social--with community reaction to the noise of aircraft around international airports in large U.S.A. cities. The seven major airports involved were Logan International-Boston, O'Hare International-Chicago, Dallas International-Dallas, Stapleton International-Denver, Los Angeles International-Los Angeles, Miami International-Miami, and Kennedy International-New York.

In the three years of work on this study, many individuals made significant contributions, all of which unfortunately are too numerous to acknowledge. Dr. Wayne Rudmose was Program Manager for the entire study. Dr. William R. Hazard directed the Sociometrics Department effort and Mr. William Connor directed the acoustical studies, and prepared the final report. Mr. Richard Edmiston was in charge of the analysis of acoustical data and performed many other important tasks. Mr. Harrold Patterson was in charge of the analysis of combined data. Mr. Ralph Wright was the field supervisor for the extensive social survey programs. Finally, special recognition is due to the advisory contributions made by Dr. Raymond Bauer, Mr. Paul Borsky, and Dr. A. C. McKennell.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Cont'd)

1. SUMMARY

The research procedure involved the acquisition of large amounts of field data concerning community characteristics, exposure to aircraft noise, and reactions to the noise. These data were then analyzed using a variety of techniques to establish and measure relationships between variables representing exposure, mediating factors, and response.

Social data were obtained by personal interviews based upon questionnaires. In the seven cities, a total of 8207 interviews were secured. Most of the respondents in each city were selected randomly from sample areas under flight paths and extending to 10 or 12 miles from the center of the airport. However, some respondents were selected from lists of noise complainants or from the membership of an anti-noise organization. The noise exposure for each respondent was determined from acoustical measurements and air traffic data. A total of over 10,000 flyover noise signatures were recorded and analyzed.

In the analysis of results, the understanding of annoyance and complaint and their relationship to the noise produced by air traffic has been significantly enhanced. For the first time, the many existing formulations of noise parameters have been compared using comprehensive physical and social data collected in airport communities. Two ways of evaluating annoyance in exposed communities with good accuracy have been developed, and the differences in annoyance observed between individuals with the same noise exposure have been explained. The major results of this study, presented in greater detail in Chapter 10, are listed below. References to pertinent sections of the report are given in parentheses.

1. Simple weighted sound pressure level values (dBA and dBN) provide adequate approximations to more complex measures for the purpose of determining community noise exposure. (5.1)

2. As measures of aircraft noise exposure in communities, the Composite Noise Rating (CNR), Noise and Number Index (NNI', as defined in this report), and Noise Exposure Forecast (NEF) are practically interchangeable, although CNR is slightly superior for predicting annoyance. (5.3.5, 6.2)

3. Installations for community monitoring of aircraft noise exposure can utilize weighted sound pressure level measurement and should be designed to obtain adequate samples of both flyover noise and ambient noise. (5.1)

4. Estimation of annoyance using noise exposure as the sole predictor is rather poor. (5.4)

5. The inclusion with noise exposure of certain attitudinal or psychological variables affords good prediction of individual annoyance. Prediction is improved by use of a nonlinear model. (6.2)

6. An equation can be written for predicting individual annoyance with good accuracy. (6.3)

7. For a significant reduction in annoyance, a CNR value of 93 or less is required. Above 107 CNR, annoyance increases steadily and above 115 CNR, noise exposure is associated with increased complaint. (6.3, 8.2)

8. Within certain limits, the number of highly annoyed households in a community may be estimated from the number of complainants. (7)

9. Since adjusting for the noise attenuation of the house lowers the correlation between exposure and annoyance, people appear to react to the noise as perceived outdoors rather than indoors. (5.5)

10. An equation for predicting complaint among a random sample, similar to the predictive equation for annoyance, can be written, but its accuracy is not good. (8.3)

11. There is a substantial difference between predictors of annoyance and predictors of complaint: predictors of annoyance are primarily physical/attitudinal; predictors of complaint are primarily physical/sociological. (6, 8)

12. Complainants are not more sensitive to noise than random respondents. The complainants are less annoyed with typically irritating noises. They are also less annoyed with usual sources of neighborhood noise except for two items--aircraft and sonic booms. (4.2)

13. On the average, complainants, in comparison to members of the random samples, tend to live nearer the airport, have higher noise exposure, and to be older, more highly educated, and more affluent. They also display a higher awareness of, and negative attitude about, aircraft operations. On the basis of a very limited sample, members of noise protest organizations tend to be similar to complainants in such characteristics. (4)

14. The seven survey cities (Boston, Chicago, Dallas, Denver, Los Angeles, Miami, and New York) show consistant patterns for mean noise exposure (CNR), negative attitudes concerning aircraft operations, high annoyance, and percentage of complainants. New York, Boston, and Los Angeles generally rate high on these variables; and Dallas, Miami, and Denver, low. (4.1)

15. Alleviation of aircraft noise annoyance by "house attenuation" programs and land zoning controls does not appear to be feasible except possibly in special cases. (5.5)

2. INTRODUCTION

This report is the final report on a three-year study performed under Contract NASW-1549. The total active period of performance was February 21, 1967 to March 27, 1970. Previous publications regarding certain aspects of this work comprise References 1 and 2.

Aircraft noise has become increasingly prevalent in U. S. communities in the last ten to fifteen years as a result of advances in aviation technology and increased air travel. For the seven cities studied, commercial operations have been increasing annually by nearly 40,000 since 1963. Concomitant with the increase in airport noise has been a public awareness of, and irritation with, this phenomenon, sometimes culminating in complaint or more vigorous opposition to airport operations. As a result, efforts are being made through noise monitoring, aircraft certification, engine noise reduction, modified flight profiles, and airport curfews to reduce the noise impact upon communities. The cumulative effect of these various approaches has yet to be ascertained, however,

It is apparent that the problem of airport noise is not likely to abate for the next several years and that the new public concern for "environmental quality," important aspects of which include noise, will demand an organized program of noise control based upon a fuller understanding of the effects of noise in airport communities than has heretofore existed.

Previous studies of community reactions to aircraft noise, performed by the U. S. Air Force in three regions of the United States in 1956-7[3] and by the Wilson Committee in London in 1961,[4,5] emphasized the description of disturbance and complaint in areas noted for high volume of aircraft activity. These studies have produced an understanding of the elements of public reaction in a descriptive sense. In addition, certain sociopsychological variables have been found which can be used to characterize subgroups of the population in terms of degrees of annoyance experienced.

The burden of the study reported herein is to extend knowledge in the area of community reaction to airport noise in the direction indicated in a report by Bolt Beranek and Newman, Inc.[6] which states: "Development of procedures for accurately predicting degrees of community response in particular airport community situations is not feasible at this time because of: (a) unknowns in defining and evaluating the influence of the multitude of sociological and economic factors, and the imperfect understanding of the decision-making processes in communities, (b) lack of development of an explicit scale for rating overt 'community response' and (c) uncertainties in response introduced by variability in noise stimuli and in individual reactions to the noise stimuli."

Clearly it is necessary to go beyond a description of aircraft noise in physical or psychophysical terms and investigate the significance of social and psychological factors in the shaping of individual and community response. The present report demonstrates and measures the effects of such factors so that community reaction can be predicted within narrower limits than heretofore and the effectiveness of noise control measures systematically evaluated.

Chapter 3 of this report describes the general framework of the research and the techniques employed. Chapters 4, 5, 6 and 7 present and discuss data analysis results. All basic data are contained in the Appendices.

3. RESEARCH FRAMEWORK

3.1 THE PROBLEM

The ultimate goal of this study is to provide a basis for policy decisions in dealing with practical aspects of the airport noise problem. While such a scientific basis necessarily should include a general understanding of the problem, it must also offer answers to the specific questions of how best to evaluate noise exposure, estimate and predict the impact of airport operation upon communities, and establish the value of different procedures designed to alleviate aircraft noise problems.

The basic research approach is a consistent extension of that employed in earlier studies of the same type. It involves the acquisition of large amounts of field data concerning community characteristics, exposure to airport noise, and responses in areas around large airports; these data are then analyzed using advanced computer techniques to establish and define relationships between physical, psychological, and social variables.

3.2 PREVIOUS RESEARCH

In planning the study guidance was derived from the results of previous studies conducted in the U.S.A. and Great Britain. A survey of the communities around three Air Force bases in the U.S.A. was conducted by the NORC in 1955-1957.[3] A total of over 2,300 interviews were obtained in this study, the results of which, though somewhat qualitative, served to isolate major acoustical and sociological variables. The British survey was conducted in 1961 by the Government Social Survey for the Wilson Committee on the Problems of Noise.[4,5] A total of 1731 adults resident within 10 miles of Heathrow (London) Airport, chosen at random from electoral registers, were interviewed. (Also 178 persons who had telephoned or written to the Ministry of Aviation to complain about aircraft noise were interviewed.)

The above British and American studies shared the same fundamental research variables—exposure and annoyance—in a simple stimulus-response model. The annoyance variables used in both studies (compared in detail in Chapter 5) were based upon reported activities disturbed and degree of disturbance by aircraft noise, scaled by the method of summated ratings. The types of activities reported to be disturbed by aircraft noise were the same in both nations. There was somewhat less agreement on the psychological or social factors that determined the degree of expressed annoyance, including susceptibility to noise in general, satisfaction with the neighborhood, perception of annoyance on the part of neighbors, and attitude toward airport activity. In focusing the research upon the relationship between noise exposure and annoyance, these studies did not explain systematically how the other variables interact with, and modify, exposure and community response. Indeed, this precluded an accurate description of the exposure-annoyance relationship.

In part, the present study iterates the above approach using similar variables and, not unexpectedly, produces similar results. The annoyance-centered analysis, found in Chapters 5 and 6, proceeds further, however, and develops a predictive model which includes the effects of variables other than noise exposure.

3.3 THE SOCIAL SURVEY

3.3.1 Questionnaires

The interview questionnaires used in Phase I (Form A) and Phase II (Form D) are given in the Appendices (Volume II of this report).

The questions of primary import are those pertaining to general attitudes and beliefs, psychological predispositions, disturbance by noise, and behavioral response. These were combined with "dummy" questions of less significance, and the whole represented as a public opinion survey dealing with neighborhood problems in general. Both prestructured and open-ended questions were used, and questions specifically concerning aircraft noise were not introduced until later in the schedule, so that the early stage of the interview can be considered "blind" with respect to subject matter. Quantitative answers were entailed by some questions, such as those dealing with "degree of disturbance." Nonverbal responses to such questions were elicited by means of an "opinion thermometer" with an unnumbered but segmented scale on which the respondent was asked to indicate his position between the stated extremes.

Pretests in Houston and Dallas were conducted in February, March, and April, 1967, as an aid in developing and refining the interview format used in Phase I. A total of 140 pretest interviews were administered. Limited pretests of the Phase II form were conducted in Austin in March, 1969, mainly for purposes of familiarization, as the Form D questionnaire is quite similar to the Form A in content and required interview technique.

3.3.2 Interviewing

Temporary field offices were established in the survey cities for conducting the required interviews. These offices were staffed by permanent TRACOR personnel who hired and trained local interviewers for the task. Interviewers were paid for training sessions and for each validated interview conducted. The majority were college students of senior or graduate standing. Interviewers were normally given specific block assignments, in accordance with the sampling plan described in the following section, with instructions to interview in every fourth household, with alternative procedures to be used if necessary to achieve the required quota.

In determining the legitimacy of the interviews, a minimum of 50 percent of all work was checked by field office personnel. These checks consisted primarily of the re-interviewing of respondents by telephone or in person on key sections of the interview schedule. Responses were then compared to the original responses recorded by the interviewer. In cases of doubt, all work returned by the interviewer involved was withheld for further checking and was not included in the data until its validity was proven to the satisfaction of the field supervisor.

Although no insurmountable problems were encountered in obtaining interviews, some difficulties occurred in large apartment complexes, in areas of civil unrest—such as the Watts community in Los Angeles, and in neighborhoods of strong ethnic concentration. These difficulties were dealt with by the field offices by such steps as the use of letters of introduction, providing escorts for interviewers, and assigning interviewers of appropriate racial background.

The refusal rate in Phase II cities was approximately 30 percent for the random sample. Among complainants and the organizationally involved, however, the incidence of refusals was much lower. For example, of the members contacted of the Allapattah Neighborhood Organization of Miami, only 14 percent declined an interview. This difference may be attributable to a fear of invasion of privacy among the general public on one hand, and on the other a willingness among the complainant and organizational samples to become involved and communicative concerning community problems.

3.3.3 Sampling Plan

The intent of the sampling procedure was to draw a representative sample of the noise-exposed population living within 12 miles of the airport in each of seven cities surveyed. The general area within which smaller interview tracts were designated was defined by imposing the patterns shown in Figures 3.1 and 3.2 upon the ends of principal runways of the subject airport. The pattern for Phase I was empirically determined using equal-PNL contours to obtain a wide range of aircraft noise exposure.[7] This pattern was modified for Phase II to increase the sampling of those exposed to higher levels of aircraft noise.

Within the general sample areas thus defined, specific census tracts or block groups were selected for interviewing on the basis of social variables. On the basis of 1960 census data, all tracts within each of four subdivisions of the sample areas were rank-ordered according to a scale of socioeconomic level and the final selection made so as to ensure heterogeneity. In particular, the highest and lowest ranked tracts of each subdivision were included in the sample. The total number of tracts in each city is given in Table 3.1.

Table 3.1 - Census Tracts Sampled, by City

Phase I		Phase II	
City	No. Tracts	City	No. Tracts
Chicago	20	Boston	61
Dallas	11	Miami	52
Denver	13	New York	169
Los Angeles	16		

In each tract or set of blocks thus determined interviewers were given specific assignments. Interviews were conducted on a random time basis, including evenings and weekends. Interviewers were instructed to interview the male head of household,

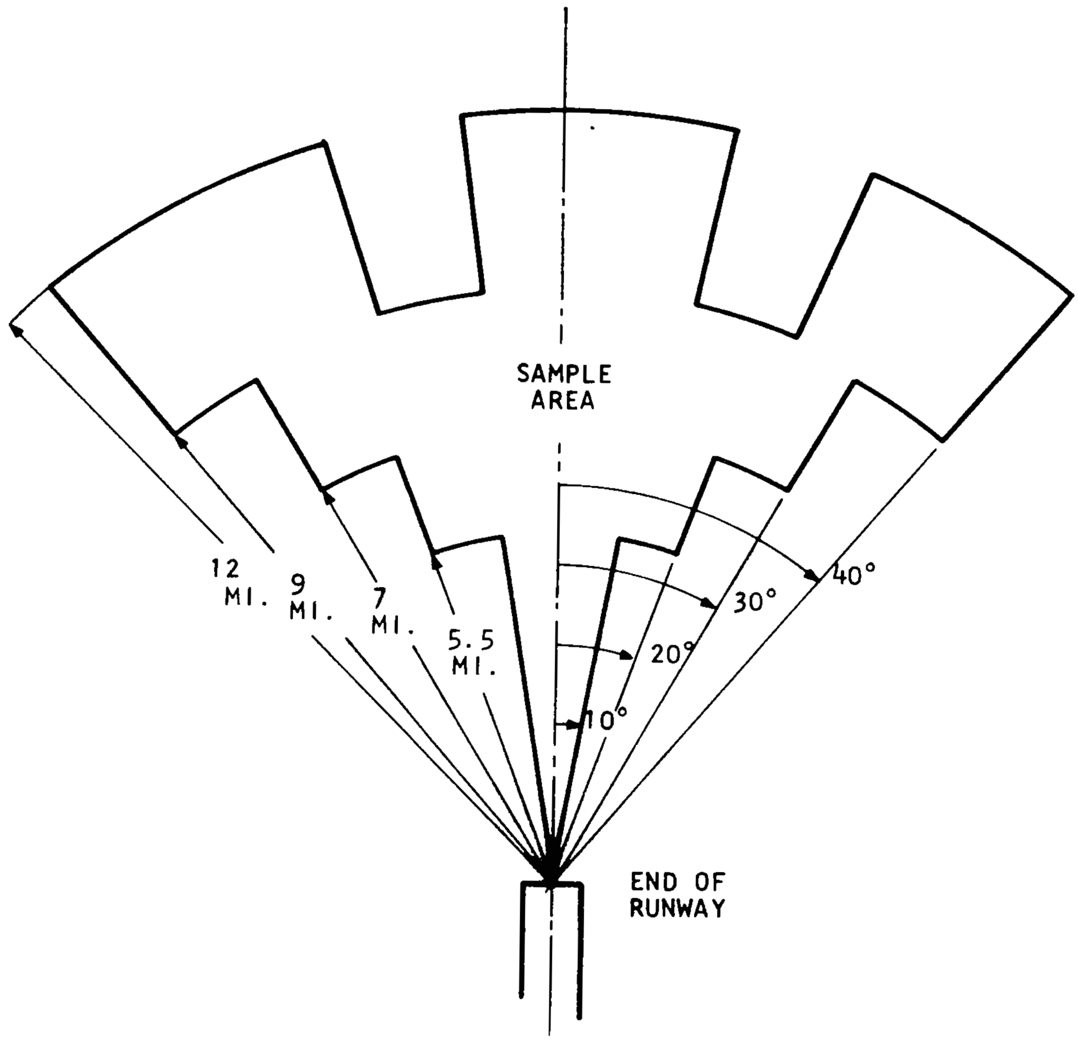

FIG. 3.1 - DEFINITION OF GEOGRAPHICAL SAMPLE AREA, PHASE I

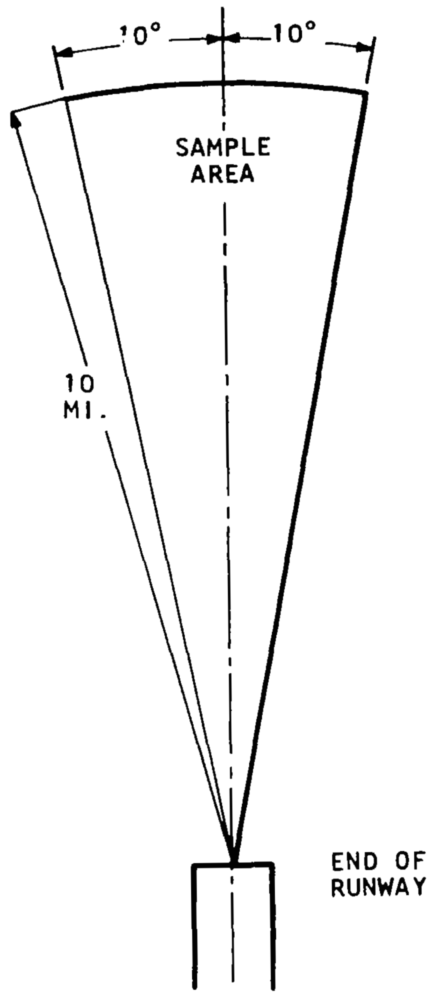

FIG. 3.2 - DEFINITION OF GEOGRAPHICAL SAMPLE AREA, PHASE II

when at home; otherwise to interview his spouse. About one-third of the sample achieved by this procedure yielded interviews with male heads of households.

The total numbers of interviews obtained in each phase and city are given in Tables 3.2 and 3.3.

Table 3.2 - Achieved Sample, Phase I

City	Survey Period in 1967	Number of Interviews			
		Residential	H[a]	B[b]	Total
Chicago	8 May-3 Aug	872	116	59	1047
Dallas	9 May-6 Jul	923	52	58	1033
Denver	24 May-10 Jul	1009	160	61	1230
Los Angeles	31 May-3 Aug	786	63	53	902
Total	8 May-3 Aug	3590	391	231	4212

a - Residents of institutions, hospitals, and rest homes.
b - Professional offices, business, schools, and restaurant patrons.

Table 3.3 - Achieved Sample, Phase II

City	Survey Period in 1969	Number of Interviews			
		Random	Complainant	Organi-zational	Total
Boston	6 Jul-5 Sep	1166	-	-	1166
Miami I	17 Mar-21 Jun	937	-	-	937
Miami II	7 Sep-15 Nov	44	41	139	224
New York	13 May-12 Sep	1070	598	-	1668
Total	17 Mar-15 Nov	3217	639	139	3995

3.4 THE NOISE SURVEY

3.4.1 Requirements for Acoustical Data

In the past decade, the measurement of noise produced by aircraft has attained a high degree of technical sophistication as a result of (a) psychoacoustical research and (b) the advent of automatic data analysis systems. At the same time a number of differing techniques for measuring aircraft noise have been employed and no comprehensive effort has been made to compare these as they relate to community response. Therefore the acoustical survey techniques for this study were devised to permit the computation of all recognized psychophysical and community noise measures. This required the construction of an analysis system similar to those now commercially available for aircraft noise certification work. The data acquisition and analysis systems and the procedures used for determining community exposure are described in detail in a previous report.[1]

3.4.2 Noise Measurements

Noise data were gathered by mobile facilities operating in the various survey cities at approximately the same time the social survey was being conducted. However, care was taken not to precede interviewers in survey areas. Within a period of two to four weeks in each city, the mobile units were operated on a 24-hour-per-day schedule and aircraft noise recordings taken in as many of the survey tracts as possible, under known modes of operation of the airport. These measurements, together with wind and airport traffic data, permitted extrapolation over a period of at least four months when establishing the exposure in any given area. Again, the procedure for this has been described previously.[1] A total of over 10,000 flyover noise signatures were recorded and analyzed. Comparisons of both basic noise parameters and noise exposure measures based on these data are given in Chapter 5.

3.4.3 Building Attenuation

In order to permit investigation of possible effects of noise attenuation of buildings upon aircraft noise exposure and hence, possibly, upon human response, an algorithm was devised for estimating values of attenuation from data acquired by the interviewers. A suitable group of questions concerning the structure of the building, types and sizes of windows, etc., was provided in the questionnaires for this purpose. The computation procedure is given in Section C-III of the Appendix.

3.5 ANALYSIS TECHNIQUES

In order to avoid discussion of specialized techniques in portions of this report dealing with data and results, a brief introduction to some of these mathematical procedures is given in this section. For more sophisticated treatments, appropriate sources are referenced. Standard texts may be consulted for information concerning well known statistical methods such as Pearsonian correlation and multiple regression.[8,9]

3.5.1 Summated Ratings

The respondent scores for a number of variables considered in this study were derived using the Likert summated ratings technique.[10] In this process, the separate scores for response categories of a set of questions, all representing a particular dimension or attribute, are summed to form a composite rating. By using a set of questions rather than a single question, greater reliability in the measurement of the dimension or attribute is obtained. An example is the variable Annoyance G in this study. The value for each respondent is obtained by summing the degree-of-distance scores for all of nine activities disturbed. Each score has a possible value of zero to five; therefore Annoyance G has a range of zero to forty-five.

3.5.2 Guttman Scale Analysis

Guttman scales are ordinal scales which have the particular properties of being unidimensional and cumulative. They are produced by a process known as "scalogram analysis."[11] Unidimensionally implies that the scale items do not involve factors or issues extraneous to the attribute being measured. The cumulative characteristic is such that a particular response to one item on the scale implies the same response to all items of lower rank.

An example from social research is the concept of "social distance." In an ideal Guttman scale on which various social relationships are ranked according to this concept, if one individual accepts a particular relationship with another—marriage, for example—this acceptance denotes acceptance of all lesser degrees of intimacy, ranked lower on the scale.

In fact such ideal scales are rarely found, but approximations can often be developed from actual data. Among a number of criteria for the usefulness of approximate scales, the most important is "reproducibility of responses." This is expressed by a coefficient and is a measure of the proportion of actual responses which fall into the ideal pattern. The minimum acceptable value for the coefficient of reproducibility was set by Guttman and his colleagues at 0.90.

While the scalogram technique provides a test of whether a given set of items forms a valid scale, it does not select items for inclusion. Contemporary computer methods, often employing the Cornell system, have greatly simplified the problem of scale item selection.[10]

3.5.3 Factor Analysis

Factor analysis is a statistical technique utilized to identify and describe underlying dimensions or "factors" that produce correlations among several indices or measures.[9,12] It is a means of reducing a large number of indices to a manageable set of conceptual variables; in addition, it often simplifies description and manipulation. In social research, underlying factors are frequently located by this procedure and those having the greatest theoretical utility are used in further research or explanation. In such cases, the indices which have the highest correlations with the useful factors are combined into summated scales which are then used to describe varying degrees of the factors possessed by members of a group. Within this report factor analysis has been utilized in the construction of many scales, including aircraft noise annoyance, noise susceptibility, attitude toward airports, attitude toward aircraft noise, fear of aircraft crash, and neighborhood satisfaction.

Although the procedures of factor analysis are somewhat complex, the fundamental idea is relatively simple. When several measures are made of a population sample, most or all of them usually group themselves into "clusters" such that each measure is correlated positively with all others in the cluster but has a low or a negative relationship with those in other clusters. Such a group of intercorrelations suggests that the measures in a cluster are all "caused" by an underlying factor which is highly correlated with all items in the cluster.

Because many clusterings among measures are possible and the objective is to produce "pure" or unrelated factors, it is necessary to utilize one of several means of "rotating" the factors in order to produce clusters whose underlying factors are as uncorrelated (or orthogonal) as possible. The degree to which a component in a cluster is correlated with a given factor is called its "factor loading" and reflects its rank order of association among other items related to that factor. If the factors isolated by rotation are found to be theoretically useful, it is then possible to work conceptually with these as variables which include the effects of several related measures.

3.5.4 Automatic Interaction Detection

If a large field of variables is available, as in this study, a means of selecting a best group of predictors of a dependent variable is needed. A method well suited to this task is Automatic Interaction Detection (AID).[13] AID does two things: (1) it constructs a chain of variables best able to account for variation in the dependent variable and (2) it determines whether or not any statistical interaction effects are present. The latter function is important since interaction among the predictors greatly influences results obtained from multiple regression and especially from MCA (discussed in Section 3.5.5), which assumes no statistical interaction.

The AID process performs a series of binary splits among the variables, each such that the means of the two resulting groups together account for more of the variance in the dependent variable than do those for any other split. Each of the two groups is then treated in the same way. The result of this process is a number of small unique groups which have differing means on the dependent variable. An examination of the "tree structure" which is formed by AID provides a basis for the selection of the most useful variables to be included in an MCA analysis; in addition, it delineates paths of additive characteristics which eventuate in high, medium, and low mean values of the dependent variables of concern.

3.5.5 Multiple Classification Analysis

A method of performing multivariate analysis which is particularly suited for certain types of social data is Multiple Classification Analysis (MCA).[14] MCA uses techniques found in dummy variable multiple regression analysis but is designed to work without the cumbersome data manipulations associated with that method. MCA will handle situations where the predictors are correlated with each other, where nonlinear relationships exist, and where measurement of the predictor variables is of the weakest sort. In other words, MCA is ideal for the type of data measurement found in social surveys; it is employed in developing the predictive equations described in this report.

Whereas a predictive equation based upon multiple linear regression analysis is of the form

$$Y = K + \sum_m \beta_m X_m,$$

the MCA technique yields a predictive equation of the form

$$Y = K + \sum_m \sum_n \alpha_{mn} X_{mn}.$$

In the latter case, each of m variables is divided into n categories, each with its own weighting α_{mn}, and X_{mn} is the response in the nth category of the mth variable. The equation for predicting Annoyance V developed in Chapter 6 of this report is of this form. It may be applied to either an individual or a group. An individual would have a response in only one category of each main variable according to his actual replies to certain questions, but a group would have responses in all categories according to the distribution of individual responses within the group.

4. SAMPLE PROFILES

In the social surveys of Phase I and Phase II, a full complement of information was elicited from each respondent in the sample. Although the majority of variables constructed from this information were later found to have little or no direct association with behavioral response to aircraft noise, the range and depth of the various social descriptors is significant. Therefore a brief presentation of the variation from city to city and the differences observed between random and complainant or organizational samples will be made in this chapter. For simplicity, most of the descriptors are represented in terms of their mean values; complete distributions by city and sample are found in Part B of the Appendix. It should be remembered that the values of the variables discussed herein pertain in each case to particular noise-exposed communities around the airport and not to the city as a whole.

4.1 RANDOM SAMPLES

The information concerning samples can be categorized loosely as demographic, socioeconomic, social, physical, attitudinal, and behavioral. Various items in each of these categories are presented in Tables 4.1 and 4.2 for the random samples in each of the seven survey cities.

Only a few striking differences are apparent in Table 4.1. The Boston and New York samples are remarkably high in the proportion of white respondents. New York respondents definitely had the highest socioeconomic status and those in Dallas the lowest. The New York group also exhibited the highest scores of all in visitation and organization involvement indices. The Boston sample was unique in geographical stability, with mean values of 33 years in the city and 19 years in the same neighborhood.

Table 4.1 - General Characteristics of Random Samples in Phase I and Phase II Cities

Category	Item	SURVEY CITY						
		Phase I				Phase II		
		CHI	DAL	DEN	LAX	BOS	MIA	NYC
Demographic	Percent male	32	29	33	33	29	40	32
	Percent Anglo	78	63	80	66	98	71	93
	Average persons per household	3.60	3.10	3.29	3.24	3.69	3.18	3.97
	Average age (years)	42.8	45.6	45.2	42.7	40.4	42.3	39.1
Socioeconomic	Percent educated past H.S.	32	26	33	32	26	39	33
	Percent income over $10,000	31	15	19	32	30	31	40
	Average occupational scale	68	57	64	63	66	67	73
	Percent home-owners	77	58	73	67	63	74	82
Social	Visitation Index	2.09	1.82	1.68	2.07	2.46	2.12	2.56
	Organization Involvement Index	1.34	0.90	1.14	1.14	1.76	0.95	1.89
	Average years in city	27	23	17	18	33	18	21
	Average years in neighborhood	11	10	8	9	19	10	13
	Moves in last ten years	1.41	2.06	2.40	2.29	1.24	1.70	1.05

Table 4.2 - Noise-Related Characteristics of Random Samples in Phase I and Phase II Cities

Category	Item	SURVEY CITY						
		Phase I				Phase II		
		CHI	DAL	DEN	LAX	BOS	MIA	NYC
Physical	1967 air carrier operations/1000	574	222	129	385	186	231	404
	Average distance from airport (miles)	7.9	4.8	5.0	5.4	4.5	4.4	5.6
	House attenuation (interquartile range-dB)	26-31	27-30	27-31	28-30	24-27	26-28	26-29
	Average CNR	107	110	100	111	108	106	115
Attitudinal	Percent high "Fear"	18	19	14	27	44	16	51
	Percent high "Susceptibility"	5	8	5	16	10	4	7
	Percent low "Adaptability"	41	45	28	56	73	53	82
	Percent high "Misfeasance"	8	8	6	17	24	18	38
	Percent low "Importance"	14	21	13	5	14	6	8
Behavorial	Percent high Annoyance G	34	26	21	49	44	22	65
	Percent complainants	5	2	3	12	13	2	22
	Percent with aircraft noise interest in first-mentioned organization	1.83	1.73	2.18	5.09	0.51	0.32	1.31

Very distinctive patterns appear in Table 4.2, especially among the attitudinal variables. The physical variables cover expected ranges, except for building attenuation, which varies only slightly from city to city. The unusually large mean distance from the airport in Chicago may be a result of buffer areas which displace the populated portions of the sample areas outward. The five attitudinal variables are those used in the annoyance prediction equation discussed in Chapter 6 and defined in Part C-I of the Appendix. There is considerable consistency in the ranking of the various samples on these variables. For example, the Boston sample ranks second in all five and the Denver sample ranks seventh on three, sixth on another, and fourth on a third. The New York group displays anomalous behavior, ranking first on three variables but fourth on "Susceptibility" and fifth on "Importance." There further appears to be a strong relationship between the noise exposure parameter CNR, the rankings on attitudinal factors, and the degree of behavioral response. The highest mean CNR, second highest overall ranking on attitudes, and greatest overt response all belong to the New York sample. The lowest rankings in all three categories are exhibited in Denver, and the next lowest, in Miami. The meaning of these associations is developed in later portions of this report on a quantitative basis using full distributions rather than means.

The samples showing greatest general similarity are those of New York, Boston, and Los Angeles, on one hand, and Miami, Dallas and Denver, on the other. Chicago occupies a position between these two groups.

4.2 COMPLAINANT SAMPLES

In New York 598 respondents known to be complainants were interviewed in addition to the 1070 chosen on a random basis. Although the latter happened to include 65 complainants, this number is too small to significantly affect the characterization of the random sample by average values. Although the complainant sample was taken from a list, most of the respondents therein lived within the sample areas used in selecting the random sample. Thus a valid comparison can be made between the two samples. Important differences exist in both descriptive and attitudinal characteristics. Table 4.3 presents such differences for selected variables. Complainants tend to live nearer the airport, have a higher aircraft noise exposure, and are older, more highly educated, and more affluent than random respondents. Complainants also display higher awareness of, and negative attitudes about, aircraft operations.

A basic question is whether complainants, on the whole, are individuals of unusually high sensitivity to noise stimuli. A detailed listing of random and complainant responses to certain interview questions offers some insight into this matter. In each interview, the respondent was asked how much he was annoyed by each item read from a list. One list contained various common and insignificant sounds which might normally be ignored; these were called "noise sensitivity" items and the responses are shown in Table 4.4. A second list contained noise sources which might be responsible for relatively high levels of noise in the neighborhood; these were denoted "noise susceptibility" items and the responses to these are given in Table 4.5.

It is remarkable that a smaller percentage of the complainants, in comparison with the randoms, were highly annoyed by every item in the "noise sensitivity" group (except for one tie). While this need not imply that complainants were less sensitive before exposure to aircraft noise, it would be difficult to argue that they are constitutionally hypersensitive individuals, in view of these results. The data of Table 4.5 are similar in the indication of

Table 4.3 - Comparison of New York Random and Complainant Samples on Selected Variables (Phase II)

Variable	Percent of Sample	
	Random	Complainant
Live within 4 miles of airport	45	67
CNR 125 or greater	18	24
Age 40 years or greater	54	66
College graduates or attended 4 years or longer	15	24
Annual income over $10,000	52	69
Notice the following manifestations of air traffic:		
Smoke	22	56
Fumes	18	50
Oil fallout	6	22
Landing lights	15	42
Feel aircraft fly too low	39	74
Feel aircraft might crash in the neighborhood	32	62
Feel aircraft noise could be reduced	84	93
Dislike aircraft noise above all else in neighborhood	40	94
Not aware of aircraft noise before moving into neighborhood	74	87

Table 4.4 - Comparison of New York Random and Complainant Samples on Noise Sensitivity Items (Phase II)

Item	Percent of Sample Highly Annoyed	
	Random	Complainant
Walking on Gritty Floors	14	6
Musical Instruments in Practice	9	8
Banging Doors	22	15
Air Hammers	47	40
Dripping Water	33	19
Whistling	6	6
Chalk Scraping on a Blackboard	49	33
Neighbor's Ringing Telephone	4	3
People Walking on the Floor Above	8	4
Chairs Scraping on the Floor	12	7
Neighbors Laughing or Quarreling	11	6
Typewriters	2	1

Table 4.5 - Comparison of New York Random and Complainant Samples on Noise Susceptibility Items (Phase II)

Item	Percent of Sample Highly Annoyed	
	Random	Complainant
Autos/Trucks	21	13
Neighborhood Children	12	7
Aircraft	81	98
Dogs/Pets	18	12
People	4	4
Cycles/Hot Rods	53	40
Trains	16	9
Sirens	23	11
Construction	31	16
Lawn Mowers	12	10
Garbage Collection	13	6
Sonic Booms	54	66

relatively lower annoyance responses among the complainant sample. Two important exceptions are the noise of aircraft and sonic booms, where the annoyance is higher. It may be inferred that the annoyance reactions of the complainants, though not exceptionally strong on the whole, have been concentrated on the noise produced by aircraft in particular.

Many of the trends noted for the New York samples can also be found in Miami, although the number of complainants is too small (N = 41) to allow statistically meaningful comparisons with the random sample. For example, in contrast to the random respondents, the Miami complainants tended to live nearer the airport, to have higher aircraft noise exposure, and to be older. The difference in attitudes related to aircraft operations was also highly pronounced.

4.3 ORGANIZATIONAL SAMPLE

A total of 139 respondents were selected from the membership of the Allapattah Civic Organization in Miami, a group which actively protests aircraft noise. Comparison of these organizational respondents with those in the Miami random sample reveals many of the same differences found between the complainants and random respondents in New York. For example, the organizational members lived closer to the airport, had higher aircraft noise exposure, were older, and had more negative feelings about aircraft activity. Given such similarities, the question arises as to what extent, if any, the organizational members and the complainants differ.

A comparison can be made only on a rough basis. It is necessary to use the Miami complainant sample, which is too small to afford an accurate characterization of the complainants. Also, since the organizational sample is drawn from a single united group, many characteristics are likely to be more representative of the particular organization than of noise-concerned organizations in general. The comparison in Table 4.6 should be examined with these strong reservations in mind. For the items in the first table group, there certainly exists a general similarity between the two samples, except for "distance from the airport," which can be explained in terms of organizational unity based on geographical proximity. Attitudinal factors and Annoyance G also show comparable patterns. It thus may be tentatively inferred that organizational members and complainants tend to be similar both in their intrinsic characteristics and in their differences from randomly chosen individuals in areas exposed to airport noise.

Table 4.6 - Comparison of Miami Complainant and Allapattah Civic Organization Samples

Variable	Percent of Sample	
	Complainant	Organizational
Live 4 to 6 miles from airport	51	93
CNR 110 or greater	68	72
Age 40 years or greater	87	78
Educated past H.S.	33	34
Annual income $15,000 or more	15	7
Annual income less than $6,000	46	53
High "Fear"	68	58
High "Susceptibility"	15	8
Low "Adaptability"	93	88
High "Misfeasance"	59	47
Low "Importance"	2	3
High noise sensitivity	20	14
High Annoyance G	81	68

5. EXPOSURE AND ANNOYANCE

5.1 NOISE PARAMETERS

The following fundamental noise parameters were provided as a function of time by the analysis system:

- PNdB1 - PNdB computed (with pure tone corrections[15]) from third-octave band data sampled once per second
- PNdB2 - As PNdB1 but without pure tone corrections
- PNdB3 - PNdB value computed (without pure tone corrections) from maximum flyover levels occurring in each third-octave band (not necessarily simultaneously), sampled once per second[16]
- PHONS - Loudness level computed according to Stevens' Mark VI method[17]
- dBN - SPL weighted according to inverse of 40-noy contour[18]; zero reference at 1 kHz
- dBA - A-weighted SPL[19]
- SIL - Speech interference level (arithmetic average of SPLs in the 1 kHz, 2 kHz, and 4 kHz octave bands).

A comparison of the values of these parameters at maximum flyover noise level for 4730 flyovers recorded during the Phase I survey is here reproduced from a previous report[1]:

Table 5.1 - Comparison of Maximum Noise Measures for 4730 Flyovers - Entries are [Mean of (M-N)]/[σ]

M	N: PNdB1	PNdB2	PNdB3	PHONS	dBN	dBA	SIL
PNdB1		2.6/1.4	1.2/1.5	4.1/2.6	9.7/2.6	14.2/3.0	25.0/2.8
PNdB2			-1.4/1.0	1.5/1.7	7.1/1.8	11.6/2.2	22.4/2.9
PNdB3				2.9/1.8	8.4/1.9	13.0/2.4	23.8/3.1
PHONS					5.5/1.8	10.1/2.0	20.8/3.8
dBN						4.6/2.1	15.3/3.9
dBA							10.8/3.8
SIL							

Although such comparisons have been made before (and generally agree with these results), that given in Table 5.1 is particularly valuable in that it represents a very large mass of acoustical data taken over a wide range of community noise exposure. From the standard deviations it is apparent that for determining noise exposure from statistical data simple measures such as dBN and dBA provide very good approximations to the more complex parameters which involve computation. The constant required for conversion of dBA readings to equivalent PNdB1, for example, can be taken from the table. It is likely that these constants will change as new aircraft or retrofits are introduced which produce modified noise spectra; however, since the pure tone content will probably be reduced, the simpler measures may correlate even better than at present with the more complex.

5.2 ANNOYANCE SCALES

5.2.1 Annoyance Measures

Although "annoyance" is a generally meaningful term, in this study as in earlier research it is desirable to establish a quantitative measure for this response. Two measures, in fact, were used in different phases of the analysis; these are denoted Annoyance G and Annoyance V.

Annoyance G was constructed in the following manner: respondents who were bothered by aircraft noise were asked by the interviewers to identify the kinds of daily activities that were disturbed by the noise, and to indicate how bothered they were using the "opinion thermometer" which was read as a scale from 1 to 5. Those who were not disturbed or who did not respond were assigned a score of 0. Annoyance G was formed by simply adding the opinion thermometer scores for all nine "activity disturbed" categories. Each respondent thus had a disturbance score of from 0 to 45, depending on his distribution of responses. The mean for this distribution was 23.2. A total of 4,153 persons in Phase I—98.6 percent of the sample—reported one or more disturbances of daily activities by aircraft noise and, correspondingly, at least some degree of bother. Table 5.2 shows, for each of nine activities disturbed, the percentage of the total respondent sample who scored 4 or 5 for that activity.

Table 5.2 - Percent Extremely Disturbed by Aircraft Noise*, by Activity Disturbed (Phase I)

Activity	Percent
TV/Radio reception	20.6
Conversation	14.5
Telephone	13.8
Relaxing outside	12.5
Relaxing inside	10.7
Listening to records/tapes	9.1
Sleep	7.7
Reading	6.3
Eating	3.5

*Percent scoring 4 or 5 on a 1-5 scale.

A somewhat more complex measure, Annoyance V, was used in developing the predictive equation described in Section 6.3 using Phase I data. Annoyance was derived from a Varimax factor analysis of annoyance-related variables: perception of neighbors being annoyed by aircraft noise, perception of aircraft noise as a city-wide problem, and past annoyance. Factor loadings (which can be thought of as equivalent to within-class correlation coefficients between each variable and the cluster of variables which represents the annoyance dimension) and standardized weights are shown in Table 5.3.

Table 5.3 - Principal Annoyance Components
(Factor Analysis - Phase I)

X	Variable	Loading	Standardized Weight
1	Annoyance G	0.7843	0.2494
2	Neighbors annoyed	.8004	.2473
3	City-wide annoyance	.6158	.2088
4	Past annoyance	.5014	.1900

Annoyance V is then given by

$$V = 0.2494\ (X1) + 0.2473\ (X2) + 0.2088\ (X3) + 0.1900\ (X4).$$

(The measure V is identical to the annoyance measure R used in a previous report on this research.[2])

Table 5.4 gives the distribution of the component variables X2, X3, and X4 for the Phase I sample.

Table 5.4 - Distribution of Variables Used in Annoyance V (Phase I) - Total N = 3590

Variable		Response 0	1	2	3	4	5
X2	N	758	958	489	472	432	481
	%	21.1	26.7	13.6	13.1	12.0	13.4
X3	N	370	386	585	846	776	627
	%	10.3	10.7	16.3	23.5	21.6	17.5
X4	N	64	1534	525	496	468	503
	%	1.8	42.7	14.6	13.8	13.0	14.0

5.2.2 Scalogram Analysis

The scale of Annoyance G was subjected to Scalogram analysis, the technique for which is discusssd in Section 3.5.2. This process here distributes the informants along a dimension representing the magnitude of annoyance.

Besides serving as a validation test of the annoyance measure used, Scalogram analysis permitted a comparison with scales used in previous studies, since the interview procedures and lists of activities disturbed were similar. This comparison for the Phase I survey is represented in Section 5.2.3.

Table 5.5 gives results for the four cities of Phase I. By reading down the columns, the percentage of informants who were annoyed with the disturbance of each activity can be determined. Disturbance of each activity implies disturbance of all other activities lower in the scale as well. For example, in Chicago 1.7 percent of the population reported disturbance in eating according to the

Table 5.5 - Scalogram Analysis for Phase I Cities

(Nine Item NASA Scales)

Chicago		Los Angeles		Denver		Dallas	
Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed
Eating	1.7	Eating	4.7	Eating	2.4	Eating	1.2
Sleeping	4.1	Sleeping	20.7	Sleeping	4.2	Reading/ Concentrating	2.4
Reading/ Concentrating	18.4	Listening to Records/Tapes	44.6	Relaxing Outside	5.3	Listening to Records/Tapes	5.0
Listening to Records/Tapes	30.6	Reading/ Concentrating	50.7	Reading/ Concentrating	8.4	Telephone Conversation	16.9
Telephone Conversation	38.3	Relaxing Outside	55.4	Listening to Records/Tapes	10.9	Sleeping	23.0
Relaxing Inside	44.8	Telephone Conversation	61.4	Relaxing Inside	12.7	Face-to-Face Conversation	27.8
Relaxing Outside	49.9	Face-to-Face Conversation	62.7	Telephone Conversation	24.0	Relaxing Outside	34.3
Face-to-Face Conversation	52.1	Relaxing Inside	66.6	Face-to-Face Conversation	26.9	Relaxing Inside	40.9
TV/Radio Reception	55.8	TV/Radio Reception	72.5	TV/Radio Reception	35.7	TV/Radio Reception	50.0
Number of Interviewees:	827	786		1,009		923	
Percent Not Disturbed:	44.2	27.5		64.3		50.0	
Coefficient of Reproducibility:	.95	.93		.90		.95	

"perfect" scale. For these persons, all other activities were also reported as disturbed by aircraft noise. An additional 2.4 percent of the informants (total of 4.1 percent) reported disturbance of sleep. For these persons, all other activities except eating were also reported as disturbed. The remaining lines are interpreted in the same manner.

Although the specific order of disturbance varies from city to city, it appears that the dominant order, from most inclusive to least inclusive, is eating, sleeping, reading or concentrating, listening to records or tapes, telephoning, relaxing outside, relaxing inside, face-to-face conversation, and TV or radio reception. Coefficients of reproducibility are acceptably high.

5.2.3 Comparison With Other Studies

Table 5.6 presents scale comparisons between the present study and the 1957 Air Force study of communities affected by SAC bases.[3] The Air Force study queried informants concerning the frequency and degree of annoyance in connection with resting, sleeping, talking, house vibration, and listening; and about general attitudes toward aircraft noise. Since these items were among those included in the NASA study, a comparison limited to these common items was feasible.

With minor variations, the order of activities disturbed in the NASA cities substantiates the order observed in the Air Force study conducted some 12 years earlier. The minimum reliability criterion is approached, but not quite met, in each case. The percentages of the population not disturbed and not annoyed cannot be compared directly since the NASA sample included a greater proportion of households with low noise exposure than did the Air Force sample.

Table 5.6 - Scalogram Analysis for SAC[3] and NASA Phase I Cities

(Six Item NASA and Air Force Scales)

SAC Cities: Disturbance Order	SAC Cities: Cumulative Percent Annoyed*	NASA Cities: Disturbance Order	NASA Cities: Cumulative Percent Annoyed
Resting (More than a little annoyed)	X	Sleeping (More than a little annoyed)	13.2
Sleeping (More than a little annoyed)	X	Relaxing Inside (More than a little annoyed)	14.0
Talking (More than a little annoyed)	X	Face-to-Face Conversation (More than a little annoyed)	22.0
Vibrations (More than a little annoyed)	21.0	Vibration (More than a little annoyed)	22.1
Listening (More than a little annoyed)	X	TV/Radio Reception (More than a little annoyed)	23.7
Resting (A little annoyed)	X	Sleeping (A little annoyed)	23.9
Sleeping (A little annoyed)	X	Relaxing Inside (A little annoyed)	27.6
Talking (A little annoyed)	X	Face-to-Face Conversation (A little annoyed)	27.8
Vibrations (A little annoyed)	X	Vibration (A little annoyed)	29.2
Listening (A little annoyed)	45.2	TV/Radio Reception (A little annoyed)	54.2
General Aircraft Annoyance	82.0	General Aircraft Annoyance	58.4
Number of Interviewees:	2,328	3,545	
Percent Not Annoyed:	18.0	41.6	
Coefficient of Reproducibility:	0.90	0.87	

*Percentage for individual disturbance not reported.

Table 5.7 presents the same type of comparison between the 1961 Heathrow (London) study[4] and the NASA Phase I study, by city. Among responses in the category called "various activities" were such things as visiting, strolling, praying, participating in or viewing sporting events, and shopping. Only two salient differences appear between the British and U.S.A. cities. London residents reported less disturbance of sleeping, possibly because of restrictions on the noise of night operations in effect at the time of the survey. Interruption of TV/radio reception was higher in order in London and therefore more indicative of other disturbances. The latter difference may well reflect cultural differences, i.e., a higher value placed upon this activity among the British. The coefficient of reproducibility supports the use of the scales to establish annoyance measures.

5.3 MEASUREMENT OF AIRCRAFT NOISE EXPOSURE

Historically, several formulations have been used to produce a single-number index of noise exposure. Several of these were evaluated using Phase I data to determine which yields the highest statistical significance in predicting annoyance. The three accepted formulations are the Composite Noise Rating (CNR), Noise and Number Index (NNI), and Noise Exposure Forecast (NEF). These differ primarily in their treatment of three fundamental components: a scale value of aircraft flyover noisiness based on the results of psychophysical experiments, the number of aircraft operations, and the time of day (simply categorized as daytime or nighttime). Another measure considered was the cumulative time during the day in which the Speech Interference Level (SIL) of aircraft noise exceeded certain values. These times were included in the analysis in both linear and logarithmic form.

The aircraft noise exposure was determined in each city for a period of at least three months, just before the interviews were conducted.

Table 5.7 - Scalogram Analysis for London[4] and NASA Phase I Cities

(Six Item London and NASA Scales)

London		Chicago		Los Angeles		Denver		Dallas	
Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed	Disturbance Order	Cumulative Percent Annoyed
Various Activities	6	Various Activities	4	Various Activities	7	Various Activities	3	Various Activities	5
House Vibration	18	Sleeping	24	Sleeping	35	Sleeping	19	Sleeping	22
TV/Radio Reception	28	House Vibration	44	House Vibration	60	House Vibration	31	Face-to-Face Conversation	40
Face-to-Face Conversation	41	Face-to-Face Conversation	51	Face-to-Face Conversation	66	TV/Radio Reception	36	House Vibration	49
Sleeping	57	TV/Radio Reception	56	TV/Radio Reception	68	Face-to-Face Conversation	37	TV/Radio Reception	52
General Aircraft Annoyance	86	General Aircraft Annoyance	65	General Aircraft Annoyance	80	General Aircraft Annoyance	49	General Aircraft Annoyance	67
Number of Interviewees:	1,909		827		786		1,009		923
Percent Not Annoyed:	14		35		20		51		33
Coefficient of Reproducibility:	.96		0.96		0.95		0.98		0.96

An earlier report[1] described in detail the procedures used, which included both on-site noise measurements and extrapolations where field data could not be obtained for certain areas or flight traffic conditions. For all the noise exposure measures computed, day and night periods were taken as 0600-2100 and 2100-0600 hours, respectively, and all logarithms are taken to base 10.

5.3.1 Composite Noise Rating

The CNR computation procedure[7] uses the maximum values of Perceived Noise Level (PNL) for aircraft operations, computed from noise band levels, and does not include corrections for discrete frequency components or for duration. Repetitive operations are summed on an energy basis (10 log n), and night operations are assigned a value 13 units higher than day operations. This increase in value for night operations is equivalent to a factor of 20 in the number of occurrences.

The CNR for a single class of operation j, defined as those flyovers which produce a particular noise characteristic at the point in question, is

$$CNR_j = PNL_j + 10 \log (N_{Dj} + 20N_{Nj}) - 12,$$

where N_{Dj} and N_{Nj} are the number of occurrences during day and night, respectively.

The total exposure at the site results from the operation of various types of aircraft on different flight paths, given by the energy sum of the CNR_j:

$$CNR = 10 \log \sum_j \text{antilog} (CNR_j/10).$$

5.3.2 Noise and Number Index

The NNI values are computed from an energy average of maximum flyover PNL values, designated APNL, and a total operations count N, according to the equation,

$$\mathrm{NNI} = \mathrm{APNL} + 15 \log N - 80.$$

This measure applies to a specific period, such as one day or one night. A comparison between daytime and nighttime NNI values leads to the tentative conclusion that there is an effective difference of about 17 NNI units between day and night exposures, the night exposure having the larger value.[5] For comparison with other exposure measures, it appeared advisable to form a modified NNI, designated NNI', to account for both day and night operations:

$$\mathrm{NNI}' = 10 \log(\mathrm{antilog} \frac{\mathrm{NNI}_D}{10} + \mathrm{antilog} \frac{\mathrm{NNI}_N + 17}{10}),$$

where NNI_D and NNI_N are the values determined for day and night.

5.3.3 Noise Exposure Forecast

Using procedures specified by FAA,[20] values of NEF were computed from the basic noise data. In contrast to CNR and NNI, NEF incorporates a flyover noise description, Effective Perceived Noise Level (EPNL), which includes compensation for the effects of discrete frequency components and of duration upon judged noisiness. Further, a day-night differential of 12 NEF units (equivalent to a 50/3 ratio in number of operations) and energy summation over all operations are specified. The partial NEF for a single class of operation j is given by

$$\mathrm{NEF}_j = \mathrm{EPNL}_j + 10 \log(N_D + \frac{50}{3} N_N) - 88,$$

and the exposure summed over all operations is

$$\mathrm{NEF} = 10 \log \sum_{j} \text{antilog } (\mathrm{NEF}_j/10).$$

5.3.4 Speech Interference Measures

The exposure measures derived from SIL data reflect duration of exposure, rather than number of exposures. Specifically, these are the number of seconds during the daytime in which the SIL of aircraft noise exceeded certain threshold values. The SIL data were introduced as measures of communications interference because such interference may be a prominent form of disturbance. The SIL values were computed as averages of the SPL's in the 1 kHz, 2 kHz, and 4 kHz octave bands. Although it has been shown that a somewhat different formulation may be a better predictor of speech interference,[21] there is very little difference for the restricted type of noise considered here; also, the formulation used is consistent with older data, making comparisons simpler. The selected threshold values were 60 dB and 75 dB, representing the aircraft SIL's measured outdoors above which persons outdoors and indoors, respectively, are likely to experience serious disruption of speech communication. The durations in seconds above these levels are denoted D_{60} and D_{75}.

5.3.5 Comparison of Noise Exposure Measures

For noise survey data taken in Phase I cities, the above exposure measures were found to be rather well correlated. Table 5.8 gives the coefficients computed from survey tract data. It is apparent that CNR and NNI' are essentially interchangeable. Since many of the correlation coefficients are substantially higher than the value of 0.35 which is typical for the exposure/annoyance relation (discussed in the following section), the choice of noise exposure measure is not particularly critical if exposure in a community as a whole is being determined as an estimate of annoyance.

Table 5.8 - Correlations Between Noise Exposure Measures (Phase I)

	CNR	NNI'	NEF	D_{60}	D_{75}	log D_{60}	log D_{75}
CNR		0.99	0.90	0.70	0.64	0.84	0.78
NNI'			.88	.70	.64	.88	.78
NEF				.60	.48	.71	.69
D_{60}					.93	.75	.80
D_{75}						.64	.76
log D_{60}							.81
log D_{75}							

Figures 5.1 and 5.2 are scattergrams of CNR vs NEF and CNR vs NNI' for the survey tracts of Phase I. In Figure 5.1, the slope of the least-squares regression line is 0.97; in Figure 5.2, the slope is 0.84. If exposure values in the lowest exposure zones are ignored, unity slope may reasonably be assumed in both cases, leading to the useful approximations

$$\text{CNR} = \text{NEF} + 72 \qquad (\sigma = 6.0),$$
$$\text{CNR} = \text{NNI}' + 56 \qquad (\sigma = 3.2).$$

5.4 CORRELATION OF EXPOSURE AND ANNOYANCE

Table 5.9 gives product moment correlation coefficients between Annoyance G, Annoyance V, and the three exposure measures CNR, NNI', and NEF, calculated from the data for the 3590 respondents of Phase I.

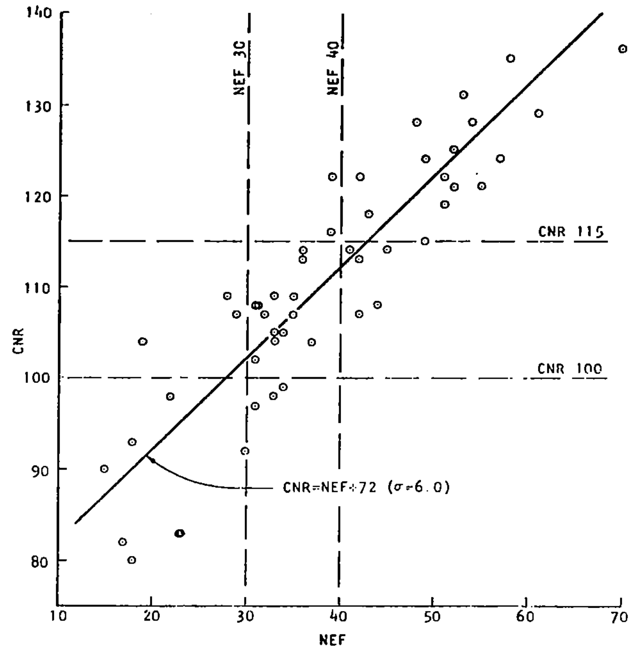

FIG. 5.1 - CNR AND NEF VALUES FOR 51 SURVEY AREAS IN PHASE I CITIES WITH NOISE EXPOSURE ZONE LIMITS INDICATED

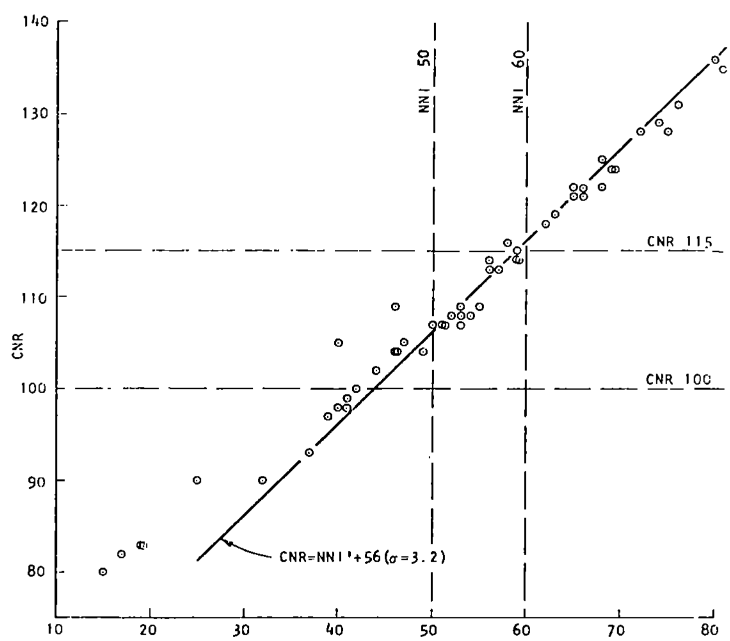

FIG. 5.2 - CNR AND NNI' VALUES FOR 51 SURVEY AREAS IN PHASE I CITIES WITH CNR ZONE AND NNI CRITICAL RANGE LIMITS INDICATED

Table 5.9 - Correlations Between Individual Noise Exposure and Annoyance (Phase I)

Annoyance Measure	Exposure Measure		
	CNR	NNI'	NEF
G	0.37	0.34	0.32
V	0.33	0.31	0.30

As a result of the large sample size, confidence intervals are small. For example, the 95 percent confidence interval for G/CNR correlation is 0.335-0.384. CNR is the best predictor of annoyance and there is no significant difference between the other two measures.

In general, however, the value of noise exposure alone as an annoyance predictor is rather poor. This is a typical result of such investigations. In the Heathrow Airport study,[4] a correlation coefficient of 0.46 was obtained between individual annoyance scores and noise exposure. In a study of traffic noise, an examination of "dissatisfaction scores" and a measure called "Traffic Noise Index" produced a correlation coefficient of 0.29.[22] A significant improvement in the prediction of annoyance can result from the inclusion of additional predictor variables, as discussed in the next section of this report.

5.5 EFFECT OF HOUSE ATTENUATION

Both Phase I and Phase II questionnaires included questions concerning building construction, answers to which were used to estimate the attenuation of aircraft noise by the structure according to the procedures described in Part C of the Appendix. A fundamental question is whether the acoustic attenuation of dwellings reduces the effective noise exposure sustained by residents and thereby modifies their annoyance reaction. If this is the case, then subtracting from the noise exposure variable the noise reduction (NR) of the building (thus computing an "indoors" noise exposure) should increase the correlation between exposure and annoyance. A correlation analysis of both Phase I and Phase II (random sample) data, the results of which are shown in Table 5.10, showed that in fact the correlation was reduced. It may be concluded that, on the whole, respondents reacted to aircraft noise as it would be perceived out of doors rather than indoors.

Table 5.10 - Product-Moment Correlation Coefficients for Annoyance G as Predicted by CNR With and Without Correction for Building Attenuation

Sample	Exposure Variable	
	CNR	CNR-NR
Phase I	0.37	0.21
Phase II	.49	.25

6. MULTIVARIATE ESTIMATION OF ANNOYANCE

6.1 ANALYSIS TECHNIQUES

Previous studies have shown that annoyance is related not only to noise exposure but also to attitudes and beliefs such as fear of crashes in the neighborhood, feelings about the considerateness of airport officials and pilots, and feelings about the physical condition of people exposed to aircraft noise.[3,4] However, an examination has yet to be made of the relationships of these things to annoyance within the context of a mathematical model. To obtain a better understanding of annoyance, consideration of its components is necessary.

Multivariate procedures, in which several predictor variables are used to estimate a given level of a dependent variable, must be used for such an analysis. The conventional techniques of multivariate analysis (e.g., analysis of variance, multiple linear regression, and discriminant analysis) are not suitable because they impose rather strict requirements (quantitatively measured data, uncorrelated predictors, and linear relationships) upon the variables which the social variables do not in general meet. A suitable method of performing this type of analysis is Multiple Classification Analysis (MCA), which will handle situations where the predictors are correlated with each other, where nonlinear relationships exist, and where measurement of the predictor variables is of the weakest sort. The selection of a reasonable number of predictor variables for the MCA process was accomplished by Automatic Interaction Detection (AID), which accomplishes two important tasks: (a) it constructs that chain of variables best able to account for variation in the dependent variable, and (b) it shows whether or not statistical interaction effects are present. (MCA assumes the absence of such effects.) MCA and AID are discussed more fully in Sections 3.5.4 and 3.5.5.

The purpose of the analysis which follows is to develop and validate a predictive equation for annoyance. The following steps were involved:

1. A predictive equation for annoyance was developed using Phase I survey data.

2. This predictive equation was used to compute "predicted" values of annoyance for the respondents in the Phase II survey.

3. The correlation between "predicted" and actual values of annoyance for Phase II respondents was examined.

6.2 SELECTION OF PREDICTORS (PHASE I)

More than 200 characteristics of population near large airports were selected, in part from previous research by others, for study in relation to community annoyance. Survey data were obtained by means of individual personal interviews according to the procedures described in Section 3.3. Variables were typically constructed from responses to a series of statements in the survey questionnaire. In this case the variable was derived by the method of summated ratings, i.e., values were obtained by adding an individual's scores for a set of related statements. Many of the social indicators found to be correlated with annoyance were constructed in this manner.

Using a combination of exploratory techniques (frequencies, cross-tabulations, AID, etc.) the total number of variables was reduced from over 200 to approximately 20 which appeared particularly salient. No serious interactions were apparent among these. Some results of the AID analysis are presented in Table 6.1, which shows the behavior of several important variables as annoyance ranges from high to low. In the case of "Fear" a strong monotonic progression from "very high" to "below average" is displayed, for example. "Miles from Airport," on the other hand, shows an increase followed by a decrease; the need for a means of dealing with nonlinear variables is apparent. The upper extreme of the scale provides a characterization of the highly annoyed: they perceive increased air traffic, are highly fearful of aircraft crashing, live within five miles of the airport in Los Angeles or Chicago, and rank medium to very high in noise susceptibility.

An MCA treatment of the 20-odd variables from Phase I data produced a set of seven which best explain Annoyance V. These are:

1. Fear of aircraft crashing in the neighborhood

2. Susceptibility to noise

3. Distance from the airport

4. Noise adaptability

5. City of residence

Table 6.1 - Results of Aid Analysis: Population Subgroups by Mean Annoyance (Phase I)

Group	Mean Annoyance (0-15)	Perception of Increase in Air Traffic	Fear of Aircraft Crashing	Miles from Airport	City	Noise Suscep-tibility	Noise Adapt-ability	Perception of Mis-feasance	Perceived Importance of Airport
1	10.8	Yes	Very High	0-5	LA, CHI	Med-Very High	-	-	-
2	10.6	Yes	Very High	0-5	LA, CHI	-	-	-	-
3	9.9	Yes	Very High	0-5	-	-	-	-	-
4	9.6	Yes	Very High	0-5	DAL, DEN	Above Avg	-	-	-
5	9.1	Yes	Above Avg	6-14	-	Very High	-	-	-
6	9.0	Yes	Very High	0-5	DAL, DEN	-	-	-	-
7	9.0	Yes	High	0-5	-	Very High	-	-	-
8	8.5	Yes	Above Avg	0-5	-	-	-	-	-
9	8.5	Yes	High	0-5	LA, CHI	Low-High	Unadapt.	-	-
10	8.3	Yes	High	6-14	LA	Low-High	-	High	-
11	8.2	No	Above Avg	3-4	-	Above Avg	-	High	
12	7.9	Yes	Above Avg	-	-	-	-	-	-
13	7.7	Yes	High	0-5	-	-	-	-	-
14	7.6	Yes	Below Avg	0-5	-	Very High	-	-	-
15	7.5	Yes	High	0-5	-	Low-High	Unadapt.	-	-
16	7.2	Yes	Below Avg	0-5	-	Very High	-	-	-
17	7.1	Yes	Very High	0-5	DAL, DEN	Below Avg	-	-	-
18	7.1	Yes	Very High	0-5	LA, CHI	Low	-	-	-
19	6.9	Yes	Above Avg	6-14	LA	Low-High	-	-	-
20	6.8	Yes	High	0-5	-	Low-High	-	-	-
21	6.7	No	Above Avg	5-6	LA	Low-High	-	-	-
22	6.5	Yes	Moderate	-	-	Low-High	Unadapt.	-	Low
23	6.5	No	Very High	0-4	-	-	-	Low	-
24	6.4	Yes	High	0-5	DAL, DEN	Low-High	Unadapt.	-	-
25	6.4	Yes	Below Avg	-	-	Low-High	-	-	High
26	6.4	Yes	Below Avg.	-	-	Very High	-	-	-
27	6.3	No	Above Avg	0-4	-	Above Avg	-	High	-
28	6.2	Yes	-	-	-	-	-	-	-
29	6.1	No	High	0-2	-	Above Avg	-	High	-
30	6.0	Yes	Above Avg	6-14	-	-	-	-	-

Table 6.1 (Continued)

Group	Mean Annoyance (0-15)	Perception of Increase in Air Traffic	Fear of Aircraft Crashing	Miles from Airport	City	Noise Suscep-tibility	Noise Adapt-ability	Perception of Mis-feasance	Perceived Importance of Airport
31	6.0	No	Above Avg	0-4	CHI	Below Avg	-	High	-
32	5.9	Yes	High	0-5	-	High	Mod-Adapt.	-	-
33	5.6	Yes	Moderate	0-5	-	Med-High	-	-	-
34	5.6	Yes	Below Avg	0-5	-	Very High	-	-	-
35	5.5	Yes	Moderate	-	-	Low-High	-	-	Low
36	5.4	Yes	Above Avg.	6-14	-	Low-High	-	-	-
37	5.4	Yes	Below Avg	-	-	Low-High	-	-	-
38	5.3	Yes	Above Avg.	6-14	CHI, DAL, DEN	Low-High	Low-Mod.	-	-
39	5.2	No	Above Avg	0-2	-	Above Avg	-	High	-
40	5.0	No	Above Avg	0-4	-	-	-	High	-
41	5.0	Yes	Below Avg	6-14	-	Very High	-	-	-
42	5.0	Yes	Below Avg	-	-	-	-	-	-
43	4.9	Yes	Above Avg	6-14	CHI, DAL, DEN	Low-High	-	-	-
44	4.8	Yes	Below Avg	0-5	-	Med-High	-	-	-
45	4.8	Yes	Above Avg	6-14	LA	Low-High	-	Low	-
46	4.7	Yes	Below Avg	-	-	Low-High	-	-	Low
47	4.7	Yes	High	0-5	-	Low-High	Mod-Adapt.	-	-
48	4.5	Yes	Moderate	-	-	Low-High	Mod-Adapt.	-	Low
49	4.4	Yes	Below Avg	-	-	Low-High	-	-	-
50	4.3	No	Above Avg	5-14	LA	-	-	-	-
51	4.3	Yes	Below Avg	-	-	Med-High	-	-	-
52	4.2	Yes	Below Avg	0-5	-	Med-High	-	-	-
53	4.1	No	Below Avg	0-5	LA, CHI	Above Avg	-	-	-
54	4.1	No	Above Avg	0-4	-	-	-	-	-
55	4.0	Yes	Below Avg	-	-	Low-High	-	-	-
56	3.9	No	Above Avg.	5-14	LA	Low-High	-	-	-
57	3.5	Yes	Low	-	-	Low-High	-	-	Low
58	3.4	Yes	Above Avg	6-14	CHI, DAL, DEN	Low-High	Adaptable	-	-
59	3.4	Yes	High	0-5	-	Below Avg	Mod-Adapt.	-	-

Table 6.1 (Continued)

Group	Mean Annoyance (0-15)	Perception of Increase in Air Traffic	Fear of Aircraft Crashing	Miles from Airport	City	Noise Suscep-tibility	Noise Adapt-ability	Perception of Mis-feasance	Perceived Importance of Airport
60	3.4	Yes	Below Avg	6-13	-	Med-High	-	-	-
61	3.2	No	Above Avg	0-4	-	Below Avg	-	High	-
62	3.0	No	Above Avg	-	-	-	-	-	-
63	2.8	No	Below Avg	3-5	LA, CHI	Low-High	-	-	-
64	2.7	No	Very High	0-2	-	Above Avg	-	High	-
65	2.7	No	Above Avg	0-4	-	-	-	Low	-
66	2.6	No	Below Avg	0-5	-	Above Avg	-	-	-
67	2.4	No	Above Avg	0-4	DAL, LA, DEN	Below Avg	-	High	-
68	2.4	Yes	Below Avg	-	-	Low	-	-	-
69	2.2	No	High	0-4	-	-	-	Low	-
70	2.0	No	Above Avg	7-11	LA	Low-High	-	-	-
71	2.0	No	Above Avg	5-14	-	-	-	-	-
72	2.0	No	Below Avg	0-5	LA, CHI	Medium	-	-	-
73	1.9	No	Below Avg	0-5	DAL, DEN	Above Avg	-	-	-
74	1.7	No	Below Avg	-	-	Above Avg	-	-	-
75	1.3	No	Below Avg	0-2	LA, CHI	Medium	-	-	-
76	1.3	No	-	-	-	-	-	-	-
77	1.2	No	Above Avg	5-14	DAL, CHI, DEN	-	-	-	-
78	1.1	No	Below Avg	6-14	-	Above Avg	-	-	-
79	1.0	No	Below Avg	0-5	-	Medium	-	-	-
80	.9	No	Below Avg	-	-	-	-	-	-
81	.7	No	Below Avg	0-5	DAL, DEN	Medium	-	-	-
82	.7	No	Below Avg	-	-	Medium	-	-	-
83	.4	No	Below Avg	6-14	-	Medium	-	-	-

6. Belief in misfeasance on the part of those able to do something about the noise problem

7. Extent to which the airport and air transportation are seen as important.

The first two columns of Table 6.2 show the interrelationships of these variables with annoyance. The column labeled "Etas" shows the correlation of each variable with annoyance without considering the effects of any other variable. The "Eta" is directly analogous to the product-moment correlation coefficient. The column labeled "Betas" shows the relation of each predictor with annoyance, taking into account the effects of (or controlling on) all of the other variables in the set. The "Beta" is directly analogous to the product-moment partial-correlation coefficient.

Succeeding columns in Table 6.2 show the result of adding each of the seven noise exposure measures discussed in Chapter 5 to the set of seven social variables. The extent to which each particular set of variables is related to annoyance is shown by the multiple R at the bottom of the table. This measure is directly analogous to the product-moment coefficient except that a set of variables, rather than a single variable, is related to the dependent variable. The amount of variance explained by this set is given by the multiple R^2. For the set of seven social variables the multiple R is 0.78; the amount of variance explained by these seven variables is 61 percent.

The relative effectiveness of the different noise exposure measures in predicting Annoyance V is shown by the Beta values for Noise

Table 6.2 - Evaluation of Seven Noise Parameters in Conjunction With Seven Predictor Variables (Phase I)

Variable	NOISE EXPOSURE MEASURE								
	None	None	CNR	NNI'	NEF	D_{60}	D_{75}	Log D_{60}	Log D_{75}
	Etas	Betas	Betas	Betas	Betas	Betas	Betas	Betas	Betas
Fear	0.64	0.38	0.36	0.37	0.37	0.38	0.38	0.37	0.37
Noise Susceptibility	.48	.27	.27	.27	.28	.27	.27	.27	.27
Distance	.43	.25	.19	.20	.24	.24	.23	.23	.20
Adaptability	.51	.18	.17	.18	.18	.18	.18	.17	.18
City	.28	.15	.12	.13	.13	.14	.15	.16	.14
Belief in Misfeasance	.29	.07	.06	.06	.06	.06	.07	.06	.06
Importance of Airport	.23	.05	.05	.05	.05	.05	.05	.05	.05
Noise Exposure	-	-	.16	.13	.12	.09	.08	.12	.11
Multiple R	-	.78	.79	.79	.79	.79	.78	.79	.79
Multiple R^2	-	.61	.63	.62	.62	.62	.62	.62	.62

Exposure. CNR ranks higher than any other measure and will therefore be used in the predictive equation in Section 6.3. The rank order of CNR, NNI', and NEF is the same as it was in the correlation with raw annoyance scores. The speech interference measures perform less well in linear form but in logarithmic form are approximately as effective as NNI' and NEF.

The effect of adding CNR to the social variables is an increase from 0.78 to 0.79 in the multiple R and a slight decrease in all the Betas except that for Noise Susceptibility. While the increase in multiple R is not large, this does not mean that Noise Exposure is of little significance. Indeed, the Beta values indicate that it ranks in importance with the fourth social variable, Adaptability. It is likely, however, that Noise Exposure is to some extent correlated with the Distance and City variables, thereby diminishing the effect on the Multiple R.

The major significance of this analysis is that inclusion of the selected social variables with the noise exposure measure increases the measure of correlation from 0.37 to 0.78.

6.3 PREDICTIVE EQUATION

In the MCA model, the effects of variables are summarized by the Beta coefficients for each class of each variable included in the predictive set, as shown in Table 6.3. The predictive equation employing these coefficients is presented in Table 6.4. (The definition, range, and distribution of scores for each social predictor can be found in Part C-1 of the Appendix.) The accuracy of the MCA model is represented by the proportion of variance in Annoyance V which it explains. A linear solution to the prediction of Annoyance V from the eight selected variables explained 45 percent of the variance; the nonlinear MCA model increased this to 63 percent.

Table 6.3 - Variables, Classes, and MCA Coefficients
For Prediction of Annoyance V (Phase I)

m	Variable	n	Class	α_{mn}
1	Fear of Crash	1	0	-1.87
		2	1	-1.29
		3	2	-1.30
		4	3	-0.61
		5	4	-0.45
		6	5	0.53
		7	6	0.48
		8	7	1.39
		9	8	2.13
		10	9	3.03
		11	10	3.78
2	Noise Susceptibility	1	0-4	-2.36
		2	5-9	-1.58
		3	10-14	-0.56
		4	15-19	0.00
		5	20-24	0.89
		6	25-29	1.30
		7	30-34	1.54
		8	35+	2.27
3	Distance from Airport	1	0.0-0.9	0.18
		2	1.0-1.9	0.17
		3	2.0-2.9	0.26
		4	3.0-3.9	0.94
		5	4.0-4.9	1.29
		6	5.0-5.9	0.41
		7	6.0-6.9	-0.20
		8	7.0-7.9	-0.54
		9	8.0-8.9	-0.33
		10	9.0-9.9	-1.30
		11	10.0-10.9	-0.71
		12	11.0-11.9	-0.84
		13	12.0-12.9	0.00
		14	13.0-13.9	-2.18
		15	14.0-14.9	-2.41
4	Adaptability	1	0	-0.78
		2	1	0.78
		3	2	-0.29
		4	3	-0.80
5	City (Air Traffic Volume)	1	Chicago	0.53
		2	Los Angeles	0.47
		3	Denver	-0.43
		4	Dallas	-0.62
6	Belief in Misfeasance	1	0	0.30
		2	1-2	-0.37
		3	3-4	-0.14
		4	5-6	-0.06
		5	7-8	-0.23
		6	9-10	-0.23
		7	11-12	-0.28
		8	13-14	0.00
		9	15-16	0.20
		10	17-18	0.07
		11	19-20	0.55
		12	21-22	0.34
		13	23-24	-0.06
7	Importance of Airport	1	0	-0.23
		2	1-2	0.89
		3	3-4	0.43
		4	5-6	-0.86
		5	7-8	0.13
		6	9-10	-0.19
		7	11-12	-0.10
		8	13-14	0.07
		9	15-16	0.22
		10	17-18	0.07
		11	19-20	0.25
		12	21-22	0.19
		13	23-24	0.00
		14	25-26	0.01
		15	27-28	-0.62
		16	29-30	-0.43
8	CNR	1	0-82	-1.04
		2	83-87	-0.82
		3	88-92	-0.76
		4	93-97	-0.04
		5	98-102	-0.20
		6	103-107	-0.75
		7	108-112	0.86
		8	113-117	0.23
		9	118-122	0.83
		10	123-127	0.06
		11	128-132	0.87
		12	133+	3.73

Table 6.4 - Generalized Predictive Equation for Annoyance V (Phase I)

$$V = K + \sum_{m} \sum_{n} \alpha_{mn} X_{mn}$$

$$= 4.89 + \sum_{n=1}^{11} \alpha_{1n} X_{1n} \qquad \text{(Fear)}$$

$$+ \sum_{n=1}^{8} \alpha_{2n} X_{2n} \qquad \text{(Susceptibility)}$$

$$+ \sum_{n=1}^{15} \alpha_{3n} X_{3n} \qquad \text{(Distance)}$$

$$+ \sum_{n=1}^{4} \alpha_{4n} X_{4n} \qquad \text{(Adaptability)}$$

$$+ \sum_{n=1}^{4} \alpha_{5n} X_{5n} \qquad \text{(City)}$$

$$+ \sum_{n=1}^{13} \alpha_{6n} X_{6n} \qquad \text{(Misfeasance)}$$

$$+ \sum_{n=1}^{16} \alpha_{7n} X_{7n} \qquad \text{(Importance)}$$

$$+ \sum_{n=1}^{12} \alpha_{8n} X_{8n} \qquad \text{(CNR)}$$

This indicates that in large cities other than the ones studied, 63 percent of public annoyance can be predicted from knowledge of seven characteristics of the population living within the noise exposure zones identified by CNR.

> The Multiple R of .79 was found to be significant beyond the .001 level of confidence. Confidence limits are determined by conversion to z values. The standard error of z is given by:
>
> $$\frac{1}{\sqrt{N-m-1}}$$
>
> where N = number of data units used in the analysis and m = number of variables. At the 95 percent confidence level the confidence interval is 1.96 times the standard error of z.
>
> For a multiple R =.7907, N = 2601, and m = 8 the confidence interval is equal to .0384. The confidence limits at the 95 percent level are .78 to .81.
>
> The significance of a multiple R is given by the following F-test:
>
> $$F_{k,N-k-1} = \frac{R}{1-R^2}\,\frac{N-k-1}{k}$$
>
> where N = the number of data units used in the analysis and k = the number of variables (predictors). With N = 2601, k = 8, and R^2 = .62524 and F with 8 and 2592 degrees of freedom equal to 540.55, R is significant beyond the .001 level.

Although the equation of Table 6.4 is important primarily as a predictive tool, an examination of the coefficients gives much insight into what creates annoyance. The most powerful predictor is "fear of aircraft crashing in the neighborhood." The coefficients relating this variable to annoyance increase by classes in an essentially monotonic fashion. The third variable, "noise susceptibility," shows a similar but less pronounced pattern.

In contrast to these monotonic variables, the coefficients for "distance from the airport," "belief in misfeasance," and "importance of airport" show nonlinear relationships. Quite noticeable is the peaking of the positive coefficients for "distance" at five miles from the airport rather than very close to the airport. Although the reasons for this are not fully understood, the data indicate the existence of a critical zone at this distance. More information on "misfeasance" and "importance" would be needed to explain their nonlinearity.

The MCA coefficients for the noise exposure variable CNR do not follow as consistent a pattern. However, the value of 107 CNR units is a point of division above which the contribution to annoyance remains consistently positive; below this it is negative, and below a CNR of 93 the negative contribution is considerable.

6.4 VALIDATION OF THE PREDICTIVE MODEL

The data obtained in the Phase II surveys in Boston, Miami, and New York were used to test the predictive technique just presented. However, the Phase II questionnaire did not contain all the questions required for the construction of Annoyance V, as a result of circumstances beyond the control of TRACOR. Therefore, it was necessary to use the basic measure Annoyance G for this validation of the prediction process. The coefficients for the predictive equation were recomputed with Phase I data using Annoynace G as the dependent variable. The results of this computation and a comparison with Annoyance V are presented in Table 6.5. The striking similarity in the Etas and Betas is probably due to the fact that Annoyance G is a component of Annoyance V. Half of the Beta coefficients are identical, and the order of the variables (the relative strength of each to predict annoyance) is unchanged. There is a slight loss in the percent variation explained (63 percent to 57 percent). This comparison gives sufficient confidence in the equation to proceed with the verification effort using Phase II data.

In applying the predictive equation to the Phase II data, certain decisions were made which may have somewhat affected the verification.

Table 6.5 - Comparison of Predictor Variables for Annoyance G and Annoyance V (Phase I)

Variable	Annoyance V		Annoyance G	
	Etas	Betas	Etas	Betas
Fear	0.64	0.36	0.60	0.34
Noise Susceptibility	.48	.27	.47	.27
Distance	.43	.19	.38	.17
Adaptability	.51	.17	.46	.17
City	.28	.12	.26	.12
Belief in Misfeasance	.29	.06	.28	.07
Importance of Airport	.23	.05	.22	.05
CNR	.48	.16	.43	.16
Multiple R	-	.79	-	.75
Multiple R^2	-	.63	-	.57

The variable "city" obviously presented a problem since the Phase II and Phase I cities are different. Since it was not known what actual differences produced the effects of the "city" variable, coefficients were selected on an "equivalence" basis: New York and Boston were assigned the Chicago coefficient on the basis of high air traffic volume, and Miami was assigned the Dallas coefficient since both are southern and have relatively moderate air traffic. Another problem concerns the "misfeasance" and "importance" variables. These were dichotomized in Phase II only, so that they are not comparable with the same Phase I variables except in the extreme portions of the range. Nevertheless, they were retained in the analysis.

Table 6.6 presents the results of the verification effort. The information in this table was obtained by using the predictive equation derived from Phase I data to estimate Annoyance G for the Phase II sample, by measuring actual Annoyance G from Phase II data, and then correlating the two measures. This was done for random, complainant, and organizational samples, both by city and merged. Two measures of association were computed: the product-moment correlation coefficient and the gamma measure of association. The latter is used when a "softer" measure is desired. Since annoyance could be characterized as a categorical variable, this measure may be most appropriate.

The ability of the predictive model to estimate Annoyance G appears quite good. The coefficient of 0.71 for the merged random sample represents a substantial improvement over the 0.37 value obtained using noise exposure alone as a predictor. Indeed this degree of correlation is rarely exceeded when dealing with a dependent variable of the type represented by annoyance.

The table shows that the equation predicts better for the random sample than for either the complainant or organizational samples. Since the equation was derived from a random population, this might be expected. In the random sample, mean annoyance in New York was underestimated, while annoyance in Miami and Boston was overestimated. Annoyance for all complainants was considerably underestimated, for organizational members only slightly underestimated.

62

Table 6.6 - Comparison of Predicted and Actual Annoyance G (Phase II)

Sample	N	Mean Predicted Annoyance G	Std. Dev.	Mean Actual Annoyance G	Std. Dev.	Product-Moment Correlation Coefficient	Percent Variance Explained	Gamma
Boston Random	1166	21.0	8.8	18.8	12.8	0.61	36.7	0.67
Miami Random	981	10.0	8.0	9.3	10.7	.69	47.1	.87
New York Random	1070	23.1	9.4	24.3	12.2	.61	37.1	.71
Merged Random	3217	18.4	10.4	17.7	13.4	.71	50.0	.79
Miami Complaint	41	23.3	8.2	28.7	10.6	.41	16.4	.69
New York Complainant	598	28.7	7.6	37.5	9.1	.32	10.4	.50
Merged Complainant	639	28.4	7.6	37.0	9.4	.36	12.7	.55
Miami Organizational	139	21.6	8.1	23.3	10.7	.57	29.1	.61

7. STATISTICS OF ANNOYANCE AND COMPLAINT

In certain situations, the ability to estimate the state of annoyance in a given population on the basis of complaint behavior is of practical value. The data of this study were therefore examined to determine whether a simple rule for this purpose could be established. The random samples from the seven cities of Phase I and Phase II served as the material for this investigation. Fundamental parameters for the seven cities are given in Table 7.1. In this table and the subsequent discussion, "complainant" denotes a respondent who said that he had at some time, through some channel, registered a complaint concerning aircraft noise. The "highly annoyed" are defined as those respondents scoring 21 to 45 on Annoyance G.

Table 7.1 - Annoyance and Complaint Statistics for Random Sample in Survey Areas

City	Total Sample N	Number Complainants* C	Number Highly Annoyed* H	Fraction of Complainants Highly Annoyed
New York	1,070	240	696	0.93
Boston	1,166	156	517	.81
Los Angeles	786	93	382	.86
Chicago	872	43	299	.84
Denver	1,009	33	215	.88
Dallas	923	22	236	.77
Miami	676	12	148	.67

*Note that C and H are not mutually exclusive categories.

The first natural inclination was to assume a simple ratio between complainants and the highly annoyed, so that each known complainant could be said to represent a fixed number of highly annoyed respondents. That such a relationship does not exist was apparent, however, upon examination of the values of the ratio of H to C from Table 7.1. The value of this ratio ranges in a nearly monotonic fashion from 2.90 for New York to 12.3 for Miami.

Further examination of the data revealed that a simple linear relationship does exist, however, between the number of highly annoyed households per thousand (h) and the number of complainants per thousand (c). This is given by

$$h' = 195.5 + 2.07\ c.$$

The coefficient of correlation with actual values of h is 0.976. Table 7.2 gives a direct comparison of predicted and actual values.

Table 7.2 - Prediction of Number of Highly Annoyed Households per Thousand in Survey Areas

City	h	h'	(h-h')
New York	650.4	659.8	- 9.3
Boston	443.4	472.4	-29.1
Los Angeles	486.0	440.4	45.6
Chicago	342.9	297.6	45.3
Denver	213.1	263.2	-50.1
Dallas	255.9	244.8	10.8
Miami	218.9	232.2	-13.3

The rule of estimation just given is strictly applicable only to populations similar to those chosen from the sample areas as defined in Section 3.3.3, i.e., from certain geographical patterns lying beneath principal flight paths of the airport. In order to perform estimations it is necessary to determine that complainants live within such areas and to ensure that complainants as defined earlier are counted rather than complaints, since more than one complaint may well originate from a single complainant.

If, for example, the "sample area" population around a certain airport is found to be 10,000 households and 200 complainants are located among these, the estimate of h would be

$$195.5 + 2.07 \times 20 = 237,$$

or nearly one quarter of the population.

Generalization to a large population, such as that within a ten-mile radius of the airport, is permissible if the assumption is granted that those groups outside the defined sample areas behave as do those in at least some of the actual sample areas in the study. If so, then the effects of all groups are additive and the estimation can be performed as above. It is of course necessary that no external influences such as news publicity, demonstrations, or the like are active in the area.

The linear expression for h' should be restricted in use to a range of complainants per thousand corresponding to that in Table 7.1—about 18 to 240—inasmuch as no validation exists beyond these limits.

The linear equation is most likely an approximation—although quite a good one—to a more complex function. It specifies a threshold value of 195 highly annoyed per thousand, after which complainants emerge at a fixed rate of one per every 2.07 highly annoyed. A more plausible general relation is of the form

$$H = P(1-e^{-\alpha C})$$

where P is the total population. In this case, zero complainants correspond to zero highly annoyed, and the ratio of complainants to highly annoyed increases as the percentage of either. In the asymptotic case, nearly the entire population is highly annoyed and practically all of this group are complainants. It is perhaps just as well that no population surveyed had approached this point closely enough to test the hypothetical mathematical model described here.

8. MULTIVARIATE ESTIMATION OF COMPLAINT

In Chapter 6 a nonlinear prediction equation was developed and tested for estimation of annoyance due to aircraft noise. In the present chapter a similar approach is used to predict complaint behavior on the basis of noise exposure in combination with social variables.

8.1 ANALYSIS TECHNIQUES

The analysis of complaint behavior was conducted in two phases. First, a large number of variables were selected as possibly related to complaint, partly on the basis of references to previous literature and partly by logical inference. A statistical technique known as step-wise multiple regression was then applied as a screening operation. This preliminary analysis reduced the rather large original number of variables to a manageable number, approximately 50. The multiple regression technique also indicated the relative importance of a number of these 50 variables.

Second, a Multiple Classification Analysis was conducted on the most important of this set of fifty variables. However, almost every variable in the set was examined at some point in the analysis to determine its effect on complaint. Those which had practically no effect were dropped and will not be discussed. Some variables which were important in the prediction of annoyance, but which did not contribute to the prediction of complaint, will be discussed at the conclusion of this section.

Most of the random sample from Phase II was used in this analysis. Since a preliminary analysis of the Miami sample showed that the portion from around the Opa Locka airport was atypical in responses, that portion was excluded. The nature of the noise exposure around

Opa Locka (heavy traffic but very small aircraft) was apparently affecting responses. The entire random samples in Boston and New York were used. The data from a total of 2,912 respondents were available for analysis.

Out of this random sample, 1,044 respondents voluntarily mentioned aircraft noise as the most disliked thing in the neighborhood. From this group, approximately 900 respondents provided enough data for a complete analysis.

8.2 SELECTION OF PREDICTORS

The dependent variable, complaint, was measured by allowing the respondents to indicate that they had participated in any of seven forms of complaint. These were telephoning or writing an official, signing a petition, visiting an official, attending a meeting, helping set up a committee, writing a "letter to the editor," and filing a suit. Discussing aircraft noise with someone, originally included as a form of complaint, was not utilized in this variable. Discussion is a more generalized form of behavioral response and is conceptually distinct from the other items in the list above.

The set of seventeen best predictors of complaint, as derived by the MCA process, are listed in general order of importance in Table 8.1. Comparison with the annoyance predictors listed in Table 6.2 shows that the results of the two analyses have very little in common. While rather good prediction of annoyance was afforded by eight variables, seventeen variables produce only fair-to-poor results for complaint. Noise exposure (CNR) is the highest ranked complaint predictor, while it occupies a middle position among the annoyance predictors. Also, while the latter variables were exclusively physical or psychological (attitudinal) descriptors, the predictor variables for complaint, while including some of these, also include several basic sociological measures. (All variables not previously used are defined in Part C-2 of the Appendix.)

Table 8.1 - Best Predictors of Complaint--
Random Sample (Phase II)

Variable	Etas	Betas
CNR	0.299	0.180
Pollution annoyance	.357	.152
Disturbance of weekday hours	.261	.120
Discussion of noise	.269	.113
Disturbance of weekend hours	.276	.113
Mobility	.108	.113
Ethnicity	.140	.110
Size of household	.182	.099
Occupation	.116	.092
Organizational involvement	.197	.086
Misfeasance	.218	.084
Fear	.265	.077
Visitation	.121	.065
Age	.134	.062
Rent/House cost	.123	.061
Distance from airport	.123	.037
Learned to live with noise	.200	.037
Multiple R	-	0.52
Multiple R^2	-	0.27

The social nature of complaint is illustrated by the number of sociological variables in the predictor set. Out of the 17 predictors, six are "background" variables (Mobility, Ethnicity, Size of household, Occupation, Age, and Rent/house cost), and three are "interaction" variables (Discussion, Organizational involvement, and Visitation). The relatively minor importance of attitudinal components is also obvious. Only four variables (Pollution annoyance, Fear, Misfeasance, and Learned to live with noise) are included in the predictor set. Such items as Importance of the Airport and Noise Susceptibility, which were important in the prediction of annoyance, were found to be not relevant to complaint.

It may be concluded that factors involved in the complaint process differ substantially from those in the annoyance process. Furthermore, there is obviously much more yet to be learned about complaint, in view of the relatively low Multiple R^2 value. Future research might well consider factors for which data were not available in the present study, such as precipitating events, development of habitual complaint patterns, and effect of family structure and life style.

8.3 PREDICTIVE EQUATION FOR COMPLAINT

A generalized complaint equation, similar to the annoyance equation of Chapter 6, can be written. The coefficients for this equation are given in Table 8.2 and the equation itself, in Table 8.3. The strong monotonic progressions observed in the category coefficients for annoyance prediction are not generally present here, although it appears for the first listed variables. The most powerful predictor, CNR, has a critical point of about 115 units, above and below which its contribution to complaint is respectively positive and negative. The next, Pollution annoyance, is an important new variable. This predictor measures the respondent's annoyance from smoke, fumes, oil dropout, and landing lights. Although the latter item is not strictly a pollution element, what the respondent seems to be reacting to mainly is the element of pollution from aircraft.

Table 8.2 - **Variables, Classes, and MCA Coefficients for Complaints (Phase II)**

m	Variable	n	Class	α_{mn}	m	Variable	n	Class	α_{mn}
1	CNR	1	0-99	-0.217	10	Occupation	0	0	-0.020
		2	100-109	-0.131			1	1	0.245
		3	110-119	0.013			2	2	0.118
		4	120-129	0.101			3	3	-0.061
		5	130 or greater	0.062			4	4	-0.007
							5	5	-0.011
							6	6	-0.070
2	Pollution Annoyance	1	None	-0.066			7	7	0.041
		2	Low	-0.025			8	8	0.073
		3	Medium	0.081			9	9	-0.006
		4	High	0.135			10	10	-0.035
3	Disturbance of Weekday Hours	1	None	0.067	11	Fear	1	Low	-0.043
		2	Low	-0.076			2	Medium	-0.049
		3	Medium-low	0.026			3	High	0.030
		4	Medium-high	0.161					
		5	High	-0.019	12	Misfeasance	1	Low	-0.712
							2	Medium	0.033
4	Disturbance of Weekend Hours	1	None	-0.047			3	High	0.124
		2	Low	-0.018					
		3	Medium-low	-0.046	13	Age	1	Not given	0.019
		4	Medium-high	0.071			2	29 or less	-0.079
		5	High	0.082			3	30 - 39	0.005
							4	40 - 49	0.014
5	Discussion of Noise	1	Low	-0.083			5	50 - 59	0.001
		2	Medium	-0.039			6	60 or over	-0.003
		3	High	0.047					
					14	Visitation	1	Low	-0.050
6	Mobility	1	None	0.050			2	Medium	-0.026
		2	Low	-0.063			3	High	-0.033
		3	High	0.026					
					15	Rent/House Cost	1	Below $125	-0.037
7	Ethnicity	1	Anglo	0.010			2	$125 - 274	0.027
		2	Negro	0.035			3	$275 or greater	0.001
		3	Other	-0.291					
8	Size of Household	1	1	-0.125	16	Distance from Airport	1	0 - 3 Miles	0.013
		2	2	-0.049			2	4 - 6 Miles	-0.016
		3	3	-0.030			3	7 - 9 Miles	0.029
		4	4	0.069			4	10 Miles or greater	-0.092
		5	5	0.061					
		6	6 or more	0.054					
					17	Learned to Live with Noise	1	No	0.022
9	Organizational Involvement	1	None	-0.047			2	Yes	-0.015
		2	Any	0.038					

Table 8.3 - Generalized Predictive Equation for Complaint (Phase II)

$$\text{Complaint} = \dot{K} + \sum_m \sum_n \alpha_{mn} X_{mn}$$

$$= 0.4 + \sum_{n=1}^{5} \alpha_{1n} X_{1n} \qquad \text{(CNR)}$$

$$+ \sum_{n=1}^{4} \alpha_{2n} X_{2n} \qquad \text{(Pollution Annoyance)}$$

$$+ \sum_{n=1}^{5} \alpha_{3n} X_{3n} \qquad \text{(Distrubance of Weekday Hours)}$$

$$+ \sum_{n=1}^{5} \alpha_{4n} X_{4n} \qquad \text{(Distrubance of Weekend Hours)}$$

$$+ \sum_{n=1}^{3} \alpha_{5n} X_{5n} \qquad \text{(Discussion of Noise)}$$

$$+ \sum_{n=1}^{3} \alpha_{6n} X_{6n} \qquad \text{(Mobility)}$$

$$+ \sum_{n=1}^{3} \alpha_{7n} X_{7n} \qquad \text{(Ethnicity)}$$

$$+ \sum_{n=1}^{6} \alpha_{8n} X_{8n} \qquad \text{(Size of Household)}$$

$$+ \sum_{n=1}^{2} \alpha_{9n} X_{9n} \qquad \text{(Organizational Involvement)}$$

$$+ \sum_{n=1}^{10} \alpha_{10n} X_{10n} \qquad \text{(Occupation)}$$

$$+ \sum_{n=1}^{3} \alpha_{11n} X_{11n} \qquad \text{(Fear)}$$

$$+ \sum_{n=1}^{3} \alpha_{12n} X_{12n} \qquad \text{(Misfeasance)}$$

$$+ \sum_{n=1}^{6} \alpha_{13n} X_{13n} \qquad \text{(Age)}$$

$$+ \sum_{n=1}^{3} \alpha_{14n} X_{14n} \qquad \text{(Visitation)}$$

$$+ \sum_{n=1}^{3} \alpha_{15n} X_{15n} \qquad \text{(Rent/House Cost)}$$

$$+ \sum_{n=1}^{4} \alpha_{16n} X_{16n} \qquad \text{(Distance from Airport)}$$

$$+ \sum_{n=1}^{2} \alpha_{17n} X_{17n} \qquad \text{(Learned to Live With Noise)}$$

Curvilinear behavior exists for some variables. For example, the effect of age on complaint attains a slight maximum for the 40-49 year category. Two peaks occur in the occupational variable, one just above the lowest category and the other just below the highest. For the most part, however, the patterns of the coefficients are not meaningfully consistent, reflecting the weak correlations of most variables with complaint.

The characteristics of a hypothetical individual most prone to register a complaint, on the basis of the predictive equation, are:

Subject to CNR of 120-129
Highly annoyed by smoke, fumes, landing lights, etc.
Moderate-to-highly disturbed by aircraft noise
Visits with others, discusses noise, is a member of an organization
High on fear of crash, misfeasance
Age 40-49 years
Lives 7-9 miles from airport in household of at least 4 persons
Very low occupational status
Middle range of housing cost

9. CAUSAL MODELS FOR RESPONSE TO AIRCRAFT NOISE

In another study[23] public response to sonic boom was investigated in terms of a causal model. The results suggested that response to the boom was dependent upon the development of an attitude concerning this stimulus. In the inferred sequence of events, attitude development followed hearing the boom and preceded disturbance of activities by the boom, and the degree of disturbance was in accordance with the intensity of a negative attitude developed concerning the sonic boom.

A pertinent question is whether response to subsonic aircraft noise follows the same pattern. An empirical answer to this question may be derived from the data of this study.

9.1 VARIABLES AND NOTATION

Four variables are investigated in the following analysis. These are:

V1 - Adjective Index Score (0-3)
V2 - Hearing Aircraft (0-1)
V3 - Number of Activities Disturbed (0-9)
V4 - Annoyance G (0-45)

The data used were obtained from 632 Miami respondents. At an early point in the interview, each was asked to describe his reaction to aircraft noise using up to three adjectives chosen from a list. Each adjective was later categorized as positive, neutral, or negative. As in the sonic boom study, each negative adjective was assigned a score of one, so that the range of the adjective index score is zero to three.

The variable Hearing Aircraft has only two values, corresponding to "yes" and "no." The Number of Activities Disturbed variable is based upon a list and ranges from zero to nine. Annoyance G is as described in Chapter 5.

The zero-order correlation between two variables V_A and V_B will be written $r_{A,B}$. Thus the notation $r_{A,B}\ r_{B,C}$ means "the correlation between V_A and V_B times the correlation between V_B and V_C." The partial correlation coefficient $r_{A,B.C,D}$ means, however, "The correlation between V_A and V_B, controlling on V_C and V_D."

9.2 METHOD OF ANALYSIS

The procedure employed was to construct three reasonable models using the four above variables and to test the relative validity of these models. For example if four variables are related in the sequence $V_A \rightarrow V_B \rightarrow V_C \rightarrow V_D$, then the following equations hold:

$$r_{B,D} = r_{B,C}\ r_{C,D} \qquad r_{B,D.C} = 0$$

$$r_{A,C} = r_{A,B}\ r_{B,C} \qquad r_{A,C.B} = 0$$

$$r_{A,D} = r_{A,B}\ r_{B,C}\ r_{C,D} \qquad r_{A,D.B,C} = 0$$

These equations represent relationships implied in the above sequence and the error obtained using actual data is indicative of (a) the extent to which the relationships do not obtain and (b) measurement inaccuracies.

The three models to be tested are shown in Figure 9.1. Model I implies that a negative attitude develops from hearing aircraft, which attitude in turn affects disturbance of activities, which then affects the degree of annoyance. The other two models are

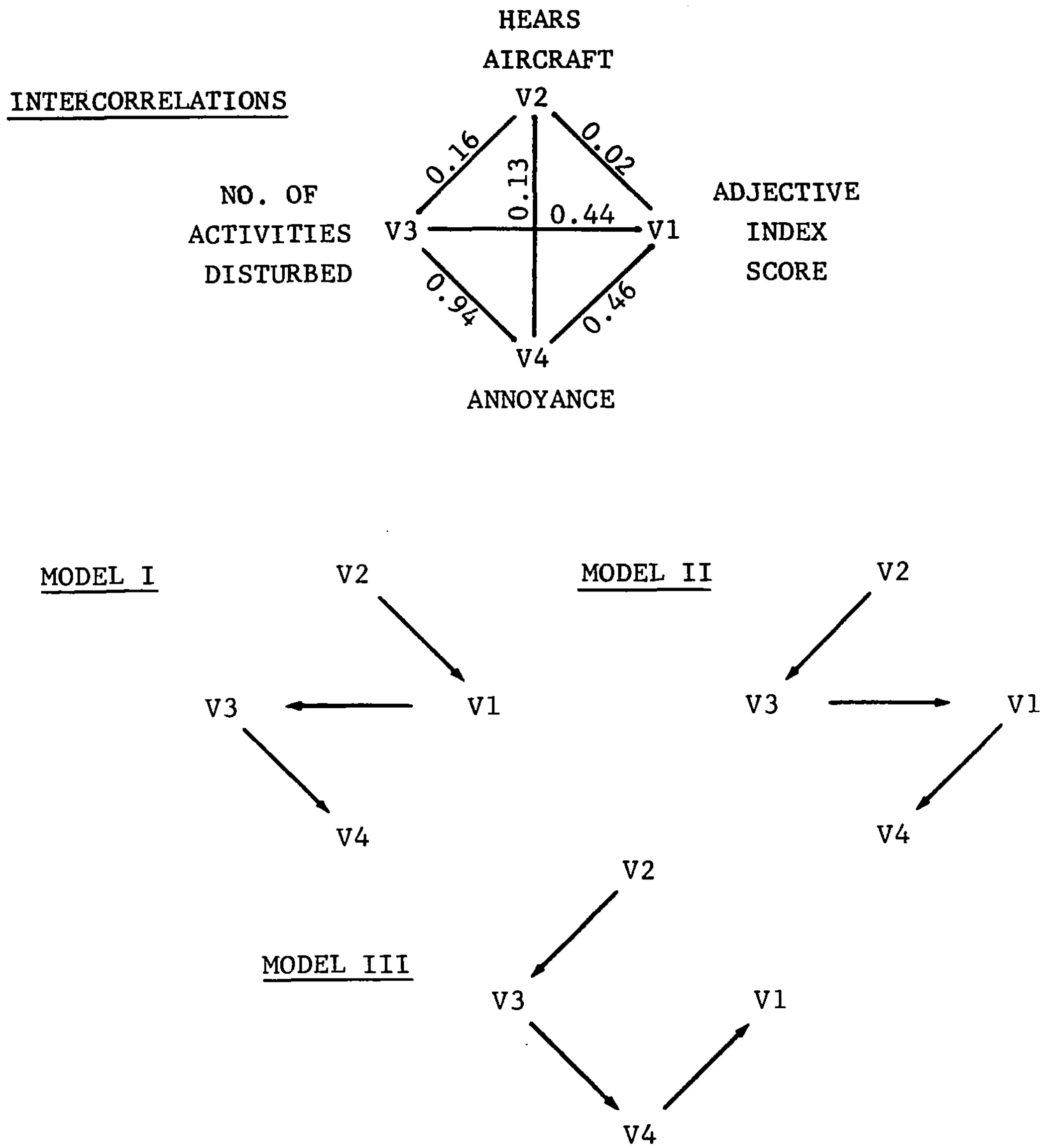

FIG. 9.1 - INTERCORRELATIONS AND HYPOTHESIZED MODELS
(Phase II, Miami Data)

similarly interpretable. Model I is similar to the preferred model for sonic boom response.

9.3 RESULTS

The results of the correlation analysis are given in Table 9.1, which presents a comparison between theoretical and actual values computed from the normal equations for each model. It is readily apparent that the only model for which the equations are satisfied within reasonable limits is Model III.

It may be concluded that, within the context of the four variables discussed, response to subsonic aircraft noise is fundamentally different from response to sonic boom. This difference may be related to the nature of the stimulus, being in one case unexpected and very brief and in the other rising and falling over a relatively long period of time. The latter time pattern is conducive upon frequent repetition, to a slow and thoughtful development of attitudes concerning the source of noise. The sharp crack of sonic boom does not provide a cue or allow time for emotional response other than that resulting from prior conditioning.

The sequential relationship of Model III, proceeding from hearing aircraft to disturbance of activities, thence to annoyance, and culminating in the formation of a negative attitude about aircraft noise, is supported by the data. This hypothetical sequence may be inferred from the results in Table 9.1, but a causal relationship cannot be rigorously proven using data of the kind available in this study. Thus it is conceivable that Model III could be succeeded by a better, more precise model, given additional information.

Table 9.1 - Evaluation of Models

Model	Hypothesized Relationships A		Hypothesized Relationships B	Actual Values A	Actual Values B
I	$r_{1,4}$	=	$r_{1,3}\ r_{3,4}$	0.46	0.41
	$r_{1,4.3}$	=	0	.15	0
	$r_{2,3}$	=	$r_{2,1}\ r_{1,3}$	.16	.01
	$r_{2,3.1}$	=	0	.17	0
	$r_{2,4}$	=	$r_{2,1}\ r_{1,3}\ r_{3,4}$	.13	.01
	$r_{2,4.1,3}$	=	0	- .06	0
II	$r_{3,4}$	=	$r_{3,1}\ r_{1,4}$	0.94	0.20
	$r_{3,4.1}$	=	0	.92	0
	$r_{2,1}$	=	$r_{2,3}\ r_{3,1}$	.02	.07
	$r_{2,1.3}$	=	0	- .06	0
	$r_{2,4}$	=	$r_{2,3}\ r_{3,1}\ r_{1,4}$	.13	.03
	$r_{2,4.3,1}$	=	0	- .06	0
III	$r_{3,1}$	=	$r_{3,4}\ r_{4,1}$	0.44	0.43
	$r_{3,1.4}$	=	0	.03	0
	$r_{2,4}$	=	$r_{2,3}\ r_{3,4}$	.13	.15
	$r_{2,4.3}$	=	0	- .07	0
	$r_{2,1}$	=	$r_{2,3}\ r_{3,4}\ r_{4,1}$	.02	.07
	$r_{2,1.3,4}$	=	0	- .05	0

10. CONCLUSIONS

The following conclusions may be derived from the preceding chapters:

1. Simple weighted sound pressure level values (dBA and dBN) provide adequate approximations to more complex measures for the purpose of determining community noise exposure.

On the basis of thousands of flyover records obtained in many different community areas, comparisons were made of all types of noise parameters, leading to this result. Corrections for estimating values of one parameter, given those of another, are given in Table 5.1.

2. As measures of aircraft noise exposure in communities, the Composite Noise Rating (CNR), Noise and Number Index (NNI', as defined in this report), and Noise Exposure Forecast (NEF) are practically interchangeable, although CNR is slightly superior for predicting annoyance.

The three measures CNR, NNI', and NEF were highly intercorrelated in the areas surveyed in this study, particularly in the range expected to be annoying. The approximations

$$CNR \simeq NEF + 72$$
$$CNR \simeq NNI' + 56$$

can be applied. CNR was a slightly better predictor of annoyance than the other two measures both on a simple linear correlation basis and for a nonlinear Multiple Classification Analysis (MCA) model utilizing social predictors as well as noise exposure.

3. Installations for community monitoring of aircraft noise exposure can utilize weighted sound pressure level measurement and should be designed to obtain adequate samples of both flyover noise and ambient noise.

Although monitoring instrumentation requirements depend upon the purpose of the installation, the basic elements include a weatherproof microphone, amplifiers and weighting filters, a detector system with rms or quasi-rms characteristic, and appropriate read-out or recording equipment. Integral and automatic system calibration should be provided. Minimal dynamic range is 40 dB for the entire system; 60 to 80 dB is desirable. In many locations it is necessary to distinguish between aircraft and other noise sources by means other than level comparison. Possible approaches are the use of directional microphones, the use of correlation techniques, and remote triggering. The feasibility of these techniques in this application has not yet been demonstrated. However, presently available technology should be adequate for this detection problem. Also, the availability of small computing systems now should make it feasible, though expensive, to compute CNR values directly from noise monitor inputs.

4. Estimation of annoyance using noise exposure as the sole predictor is rather poor.

Using the best exposure variable, CNR, comparison of predicted and measured annoyance yielded correlation coefficients of 0.37 for Phase I data and 0.49 for Phase II data.

5. The inclusion with noise exposure of certain attitudinal or psychological variables affords good prediction of individual annoyance. Prediction is improved by use of a nonlinear model.

The measure of correlation increases from 0.37 using CNR alone to 0.67 using the variables listed below in a linear model and 0.78 using them in a nonlinear (MCA) model. The seven most powerful social predictors, selected from a field of some 200 and listed with CNR in order of importance, are:

1. Fear of aircraft crashing in the neighborhood
2. Susceptibility to noise
3. Distance from the airport
4. Noise adaptability
5. City of residence
6. Belief in misfeasance by those able to do something about the noise problem
7. Extent to which the airport and air transportation are seen as important.

6. An equation can be written for predicting individual annoyance with good accuracy. The equation was derived from Phase I data and validated using Phase II data. Annoyance for complainants is not accurately estimated, however.

Use of the equation for predictive purposes requires a survey to determine the distribution of the subject community on the seven social variables. The CNR values can be obtained using published CNR or NEF contours or by computation from noise level contours and air traffic schedules.

7. For a significant reduction in annoyance, a CNR value of 93 or less is required. Above 107 CNR, annoyance increases steadily and above 115 CNR, noise exposure is associated with increased complaint.

8. Within certain limits, the number of highly annoyed households in a community may be estimated from the number of complaints.

The ratio of highly annoyed to complainants is not constant but decreases with increasing complaint. For the seven survey cities, the relationship

$$h' = 195.5 + 2.07\ c$$

where h' is the predicted number of highly annoyed households per thousand and c is the number of complainants per thousand, predicts the actual number with a correlation of 0.976. This equation is applicable to populations similar to the random sample of this study with 18 to 224 complainants per thousand households.

9. In terms of annoyance, people appear on the whole to react to the outdoor noise exposure rather than the indoor.

When the effect of the house attenuation for each respondent was included to compute an effective "indoor" exposure measure, the correlation of noise exposure and annoyance was greatly reduced.

10. An equation for predicting complaint among a random sample similar to the predictive equation for annoyance, can be written, but its accuracy is not good.

Using the 17 best predictors, the measure of correlation is 0.52. Whereas the annoyance predictors were essentially physical or psychological in nature, the complaint predictors include a number of basic social variables such as age, race, occupational status, and visitation. The most powerful predictor is CNR, the second, annoyance with aircraft smoke, fumes, oil dropout, and/or landing lights.

11. From the nature of the prediction equation variables, there is a substantial difference between factors affecting annoyance and those affecting complaint.

12. Complainants do not appear to be hypersensitive to noise, but rather are less sensitive to most noise, and more so to noise from aircraft, than are other individuals.

This conclusion is based upon study of special all-complainant samples in New York and Miami. Such persons tend to indicate less than average concern with common, potentially irritating sounds, but express greater animosity toward aircraft noise and sonic boom.

13. On the average, complainants, in comparison to members of the random samples, tend to live nearer the airport, have higher noise exposure, and to be older, more highly educated, and more affluent. They also display a higher awareness of, and negative attitude about, aircraft operations. On the basis of a very limited sample, members of noise protest organizations tend to be similar to complainants in such characteristics.

14. The seven survey cities (Boston, Chicago, Dallas, Denver, Los Angeles, Miami, and New York) show consistent patterns for

mean noise exposure (CNR), negative attitudes concerning aircraft operations, high annoyance, and percentage of complainants. New York, Boston, and Los Angeles generally rate high in these variables; and Dallas, Miami, and Denver, low.

The specific rank orderings for the random samples in these cities (highest to lowest) are:

CNR:	NYC	LAX	DAL	BOS	CHI	MIA	DEN
Attitudes:	BOS	NYC	LAX	DAL	CHI	MIA	DEN
Annoyance:	NYC	LAX	BOS	CHI	DAL	MIA	DEN
Complaint:	NYC	BOS	LAX	CHI	DEN	DAL	MIA

15. The MCA analyses provide the following profiles of a person who is highly annoyed with aircraft noise and one who is highly prone to complain.

Highly Annoyed	Complaint-prone
High fear of crash	High fear of crash
CNR over 130	CNR over 120
High noise susceptibility	Highly annoyed by aircraft smoke, fumes, etc.
Lives 4-5 miles from airport in Chicago or Los Angeles	Moderate-to-highly disturbed by aircraft noise
High "misfeasance" attitude	Lives 7-9 miles from airport
Low "importance of airport" attitude	Visits with others, discusses noise, is member of an organization
	Age 40-49
	Household of 4 or more persons
	Very low occupational status
	Middle range of housing cost

16. Alleviation of aircraft noise annoyance by "house attenuation" programs and land zoning controls does not appear to be feasible except possibly in special cases.

Annoyance correlates much better with outdoor noise exposure than indoor. It is suspected that best results from improved attenuation would be obtained when the individual involved is highly conditioned to indoor life and when the cost of the improvements is borne by others. In order to exclude the areas most highly annoyed and most prone to complaint, normal residential land usage would have to be proscribed within 5 to 9 miles from the airport in flight sectors. Within these distances, selected industrial and commercial activities might take place, but residential usage should be confined to dwellings and facilities specially adapted to the noise environment, preferably of the rental type.

17. A sequential model for stages in response to aircraft noise which is supported by the data of this study is ordered as follows:

a. Hearing aircraft
b. Disturbance of activities
c. Annoyance
d. Negative attitudes

This sequence differs from that inferred from sonic boom response data; the latter has the order a./d./b./c.

18. The scale, Annoyance G, used in this study, based upon disturbance of activities by aircraft noise, is similar to scales used in an Air Force study conducted 12 years ago in this country,

and in a British study performed 8 years ago around Heathrow (London) Airport, although the latter shows minor differences.

The scales of disturbance are Guttman scales, with the property that disturbance of a particular activity implies disturbance of all other activities ranked lower on the scale. In the present study the order is: eating, sleeping, reading or concentrating, listening to records or tapes, telephoning, relaxing outside, relaxing inside, face to face conversation, TV or radio reception. For comparable activities the order in the Air Force study was substantially the same. In the British study, sleeping was lower on the scale and TV/radio reception, higher. These differences presumably are of cultural origin.

REFERENCES

1. Connor, William K, Community Reactions to Aircraft Noise— Noise Measurements. Paper No. 40, Conference on Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft, NASA SP-189, 1968.

2. Hazard, William R., Community Reactions to Aircraft Noise— Public Reactions. Paper No. 41, Conference on Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft, NASA SP-189, 1968

3. Borsky, Paul N., Community Reactions to Air Force Noise, I: Basic Concepts and Preliminary Methodology; II: Data on Community Studies and Their Interpretation. WADD 60-689, March, 1961.

4. McKennell, A. C., Aircraft Noise Annoyance Around London (Heathrow) Airport. S.S. 337, Central Office of Information, April, 1963.

5. Committee on the Problem of Noise (Sir Alan Wilson, Chairman), Noise, Final Report. Cmnd. 2056, HMSO, London, July 1963.

6. SRDS Report No. RD-65-130, Analysis of Community and Airport Relationships/Noise Abatement, prepared by Bolt Beranek and Newman, Inc. for FAA, December 1965.

7. Anon., Land Use Planning With Respect to Aircraft Noise. AFM 86-5, TM 5-365, NAVDOCKS P-98, U. S. Dep. Defense, Oct. 1, 1964. (Available from DDC as AD 615015.)

8. McNemar, Q., Psychological Statistics (second edition), New York: Wiley & Sons, 1955.

9. Blalock, Hubert M., Jr., Social Statistics. McGraw-Hill Book Co., Inc., New York, 1960.

10. Edwards, Allen L., Scalogram Analysis; in Techniques of Attitude Scale Construction. Appleton-Century Crofts, Inc., New York, 1957, 193-198.

11. Stouffer, S. A., et al, Measurement and Prediction, Studies in Social Psychology, Vol. IV, Princeton University, 1950.

12. Thurston, L. L., Multiple-factor Analysis: A Development and Expansion of the Vectors of Mind. Chicago: University of Chicago Press, 1947.

13. Sonquist, John A., and James A. Morgan, The Detection of Interaction Effects: A Report on a Computer Program for the Selection of Optimal Combinations of Explanatory Variables. Monograph No. 35, Survey Research Center, Institute for Social Research, The University of Michigan, Ann Arbor, Michigan, 1964, Ch. IV.

14. Andrews, Frank, James A. Morgan, and John A. Sonquist, Multiple Classification Analysis: A Report on a Computer Program for Multiple Regression Using Categorical Predictors. Survey Research Center, Institute for Social Research, The University of Michigan, Ann Arbor, Michigan, 1967.

15. Proposed FAA Certification Criteria, Proposed Revision to Attachment 2, 16 August 1967.

16. R507-1966, Procedure for Describing Aircraft Noise Around an Airport, International Organization for Standardization.

17. Stevens, S. S., Procedure for Computing Loudness: Mark VI, J. Acoust. Soc. Am. 33, 1577-1585 (1961).

18. Kryter, K. D., and K. S. Pearsons, Modification of Noy Tables, J. Acoust. Soc. Am. 36, 394-397 (1964).

19. S1.4-1961, American Standard Specification for General Purpose Sound Level Meters, American National Standards Institute.

20. Bishop, Dwight E., et al, Procedures for Developing Noise Exposure Forecast Areas for Aircraft Flight Operations. FAA DS-67-10, August 1967. (Available from DDC as AD 660706.)

21. Klumpp, R. G., and J. C. Webster, Physical Measurements of Equally Speech-Interfering Navy Noises. J. Acoust. Soc. Am., Vol. 33, No. 9, Sept. 1963, 1328-1338.

22. Griffiths, I. D., and F. J. Langdon, Subjective Response to Road Traffic Noise, Journal of Sound and Vibration, 1968, 8(1), 16-32.

23. Public Reaction to Sonic Booms, TRACOR, Inc., Document No. T-70-AU-7136-U, NASA Contract NASW-1704, December 1969.

NASA-Langley, 1971 —— 2